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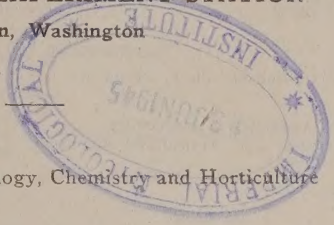

Divisions of Plant Pathology, Chemistry and Horticulture

Arsenical Spray Residue and Its Removal From Apples and Pears

by

F. D. Heald, J. R. Neller and F. L. Overley
with the assistance of G. D. Ruehle and W. A. Luce

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.
[3] In cooperation with Chelan County.
[4] On leave of absence.

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ARSENICAL SPRAY RESIDUE AND ITS REMOVAL FROM APPLES AND PEARS

By F. D. Heald, J. R. Neller, and F. L. Overley
with the assistance of G. D. Ruehle and W. A. Luce

INTRODUCTION

The use of an arsencial spray for the control of codling moth has been the standard for many years. Naturally the knowledge of the toxic properties of arsenic has raised the question as to the quantity of spray remaining on fruit at the time of harvest. Previous to the introduction of the present revolutionary methods in the handling of apples, many analyses of apples and other food products had been made. In 1914 as a result of experiments at the Maine Agricultural Experiment Station, Woods (30*) concluded that apples sprayed with lead arsenate in August did not carry sufficient arsenic or lead at the time of harvest to be of any practical importance.

A large number of analyses by Federal workers (15) were published in 1922 with a bibliography of 134 numbers. The general conclusion was that over-spraying or late spraying were the factors responsible for the large amounts of spray residue remaining at harvest time, but that when the recommendations of the Bureaus of Entomology and Plant Industry were followed "but little of the material used remains on the fruit or vegetable at harvest time."

Altho it has been pointed out a number of times in Eastern cities that some fruit from the Pacific Northwest may carry a very conspicuous arsenical residue, the complaints led to no general change in spraying practices or methods of preparing fruit for the market. It is true that this publicity was responsible for some spasmodic efforts to remove the spray residue, but in general previous to the

* Numbers in parenthesis refer to literature cited, pages 99-100.

crop of 1926, apples from the Northwest were sent to eastern and foreign markets carrying whatever residue of spray that had not been removed by natural weathering previous to harvest.

Altho a Royal Commission on Arsenical Poisoning (26) in 1903 had established a limit of permissible arsenic or a tolerance (1.429 mg. per kg.) no consistent efforts were made by our Federal Inspection forces to apply these findings to market apples until the crop of 1926. As a result of the action of English Health Authorities in the fall of 1925, the necessity of cleaning Northwest fruit was again emphasized (1, 2). The embargo on American fruit which was threatened by the English authorities, was the incentive for the enforcement of strict regulations by the Federal Food and Drug Inspection. Beginning with the crop of 1926 an attempt was made to have the fruit comply with the international tolerance of .01 grains of arsenious oxide (As_2O_3) per pound.

The belief prevailed at the beginning of the 1926 harvest that dry wiping would sufficiently lower the arsenical load of sprayed apples to comply with the tolerance of .01 grains of arsenious oxide, but the experiences of the season showed that more drastic methods of treatment would be required (12, 19, 24, 25) and preliminary work with chemical solvents was reported. Following the Spray Residue Conference at Salt Lake City the requirements for the season of 1927 were set at the international tolerance of 0.01 grains for foreign shipments and 0.025 grains of As_2O_3 for domestic trade, with the statement that all fruit, regardless of its destination, would be required to meet the international tolerance during the season of 1928. The difficulties connected with satisfactory removal have been more pronounced than anticipated, altho very good progress has been made. As a result the Food Drug and Insecticide Adiminstration has found the complete enforcement of the international tolerance impractical for the season of 1928 and will permit domestic shipments which do not exceed 0.02 grains of arsenious oxide per pound of fruit.

The problem of spray residue removal has not been confined to the Pacific Northwest, but it has been rather acute in certain

of the irrigated sections mainly for two reasons: (1) the commercial fruit production is largely in semi-arid irrigated valleys in which the fruit is rarely washed by rains during the entire growing season; and (2) the several broods of codling moth have led to late spraying and the use of heavy applications of lead arsenate. As a result apples that have not been cleaned may show a conspicuous coating of spray at harvest which may test 10-16 times the international tolerance in the extreme cases.

The spray residue problem is not as acute in other portions of the United States which may be grouped in two other classes: first, regions in which one or two cover sprays are sufficient to control the codling moth. This would include most of the apple districts of the northern and eastern sections with the latitude of New York or farther north as well as some of the western irrigated sections at higher altitudes. Second, the regions in which the summers are sufficiently warm to cause rapid multiplication of the codling moth, with consequent heavy spraying but with comparatively heavy rains during the growing season. This group will include the principal apple-producing districts of the eastern United States south of New York (17). In these districts the spray residue left at harvest time will be somewhat variable, sometimes sufficient to demand chemical cleaning, at other times below the international tolerance without any special cleaning (8, 9, 10, 16, 29). It has been shown that the amount of rainfall between the last spraying and the time of harvest is the most important factor affecting the final residue.

The serious nature of the problem has led to a nation-wide effort to meet the international tolerance (23) by all possible means: (1) the washing with chemical solvents; (2) the avoidance of excessive arsenical residue by modification of spray programs; (3) the use of substitute insecticides instead of lead arsenate; and (4) control of codling moth by other means than spraying. Altho some progress has been made along the various lines, lead arsenate is still the standard spray and chemical cleaning the most reliable method of removing the excess arsenic (5, 6, 18, 19, 20, 21, 25).

The spray residue problem is not confined to the United States as may be noted from recent reports from Canada (27) South Africa (22) New Zealand (3) and Australia (28).

The investigations presented in this bulletin have been directed principally along two lines: (1) the effectiveness of the different methods of spray removal by the various processes in the cleaning of fruit showing either normal or modified spray schedules, with main emphasis on the wet-cleaning methods; and (2) the relation of the cleaning methods to the storage behavior of apples, with special attention to calyx injury and the incidence of rots. The work then was planned to answer these two questions: (1) Can fruit be cleaned to meet the international tolerance by the machinery and processes available? (2) Can these cleaning processes be used without causing injury or decay in storage that would be prohibitive?

TYPES OF CLEANING MACHINES USED IN EXPERIMENTAL STUDIES

Wet Process Machines

The following is a list of the wet process machines which have been used in our studies conducted during the past packing season:

1. Acid process machines.
   (a) Cutler Jet, Cutler Manufacturing Co., Portland, Oregon.
   (b) Bean Rapid Fruit Washer, Bean Spray Pump Co., San José, California.
   (c) New Chemical Fruit Washer, Stebler-Parker Co., Riverside, California.
   (d) Moe Fruit Washer, Moe Iron Works, Toppenish, Washington.
   (e) Modified Orange Washer Type, Installation at American Fruit Growers, Wenatchee, Washington.

(f) Box Washer, Installations at Cashmere Fruit Growers Union, Cashmere, Washington, and Wenatchee Produce Co., Wenatchee, Washington.

2. Alkali process machine.

(a) Brogdite-Brogdex Machine, Northwest Brogdex Co., Yakima, Washington.

In addition to the work carried out at Wenatchee with these machines a few tests were made at the Irrigation Branch Station by Mr. Harry Jensen, using the Ideal Washer, (Ideal Grader and Nursery Co., Hood River, Oregon) and the Cutler Submerger. A few preliminary trials were made later in the season with the new machine made for Mr. E. A. White, Lewiston, Idaho.

In all of these machines the removal of the arsenical residue is brought about by the chemical action of either hydrochloric acid or by the alkaline bath (Brogdite*) by a soaking or drenching or spraying, or by both methods of contact, to be followed by a rinse bath of water to remove the chemical solvent and fungous spores, ending with some drying process. No detailed description of the different machines will be attempted. The half-tones (Figs. 1-8, 10), the diagrammatic representations of the principles of washing (Fig. 9, 11) and the accompanying tabulation will expain the general plans of operation of the different wet-process machines. Special features which should receive additional emphasis are the submersion of the fruit (Fig. 9) in machines (e) and (f), a number of successive dips in (e) and for the entire period in the acid tank in (f). This feature has an important bearing on the core injury in fruit varieties with a certain percentage of open calyx canals. Machines (a), (b) and (d) were originally designed by the manufacturers to use only a repumped rinse water, but since on the basis of early experience this did not give satisfactory results, an additional rinse spray was provided direct from the city water supply for those which were

* Borax 8 ozs., soda ash 2 ozs., caustic soda, 1 oz. to each gallon of water heated to 105°-110°F. Early in the packing season the caustic soda was omitted from the bath. The temperature maintained at the time of our tests varied from 92°-102° F.

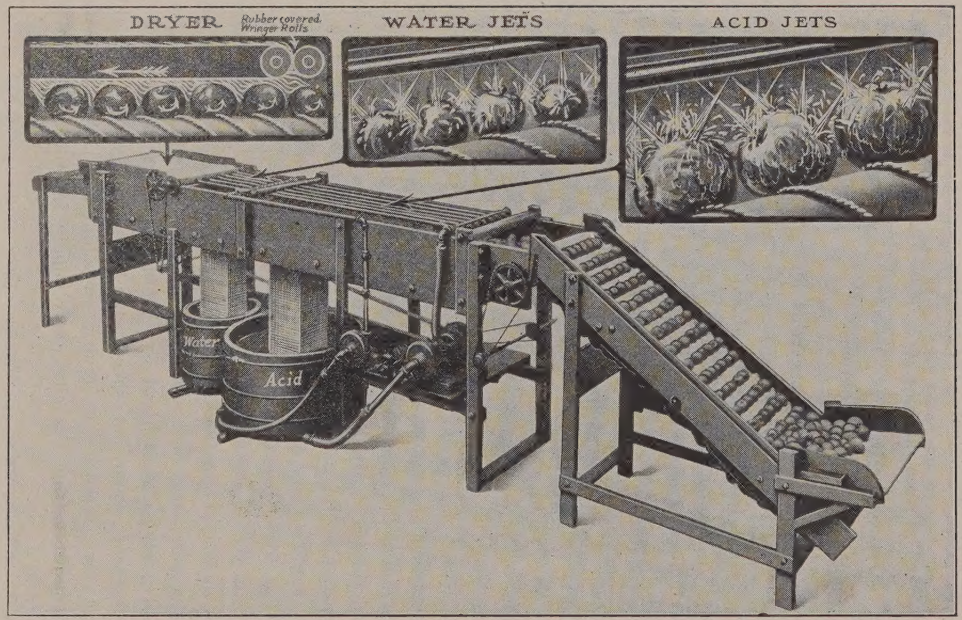

Fig. 1. The Cutler Jet Fruit Washer and drier as made by the Cutler Manufacturing Co., Portland, Oregon. Cut from F. W. Cutler.

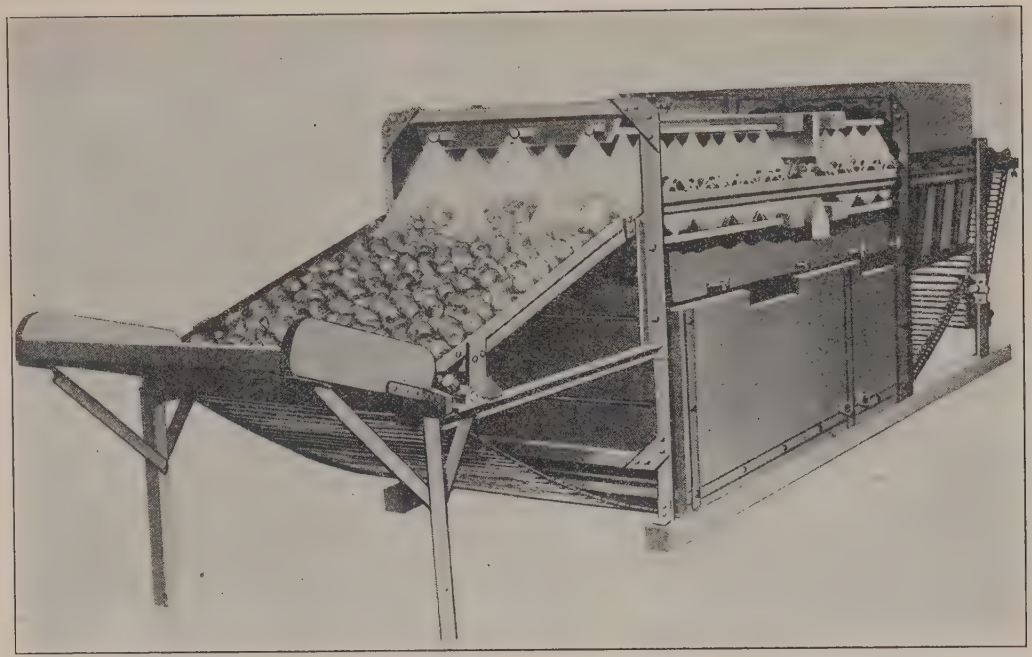

Fig. 2. The Bean Rapid Fruit Washer with sides cut away to show how the fruit is sprayed from both above and below. Air pressure dryer in the rear. Photo from the Bean Spray Pump Co., San Jose, California.

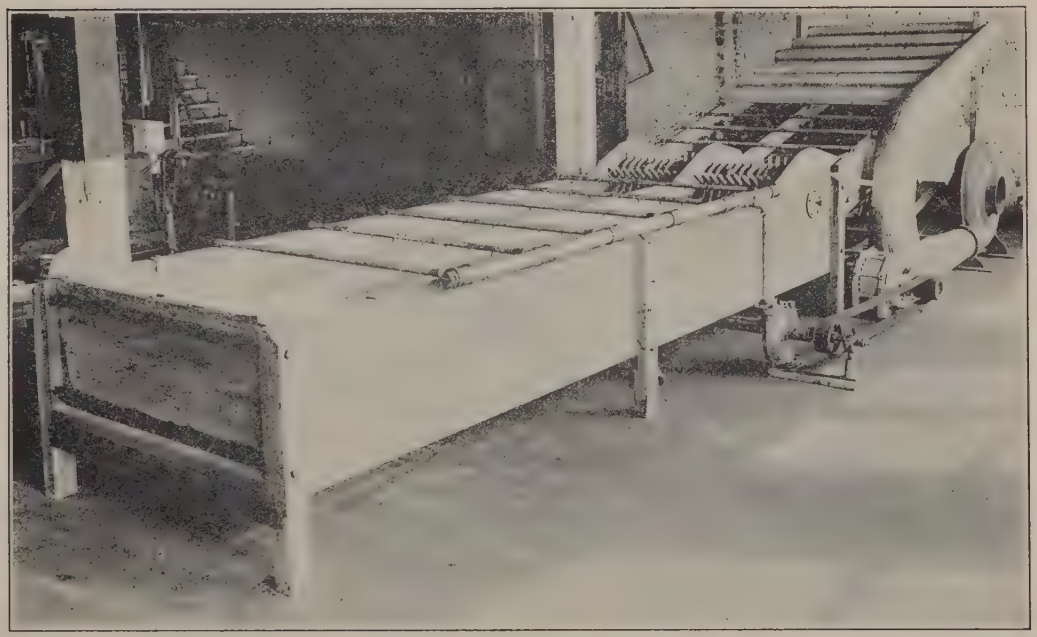

Fig. 3. The New Chemical Fruit Washer and Dryer as made by the Stebler Parker Co., Riverside, California. Photo from the Company.

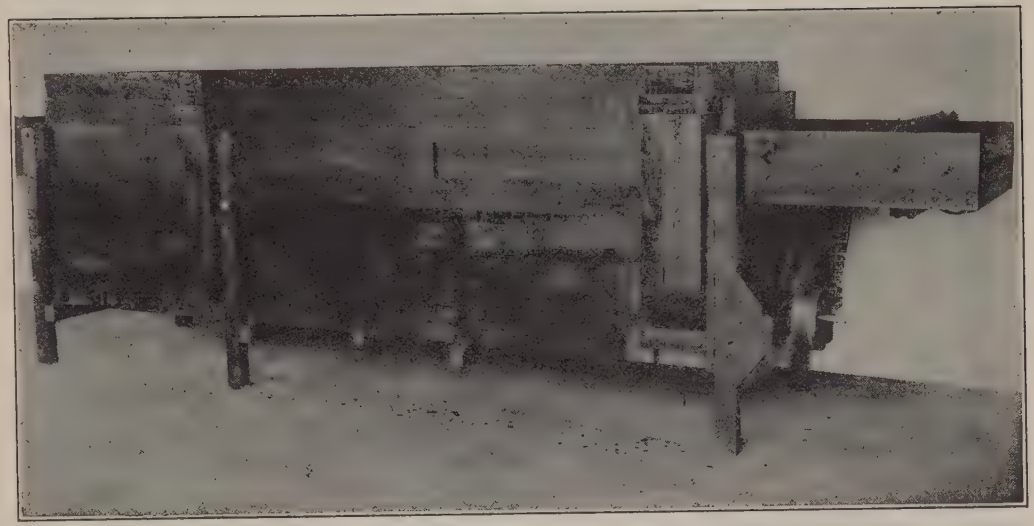

Fig. 4. The Andy Moe Chemical Fruit Washer. Photo from the Moe Iron Works, Toppenish, Washington.

Fig. 5. Modified Orange Washer type of machine as installed at the American Fruit Growers, Inc., Wenatchee, Wash. Photo by Simmer Studio.

Fig. 6. Box Dipping Machine as used at the Cashmere Fruit Growers Union, Cashmere, Washington. Photo by Simmer Studio.

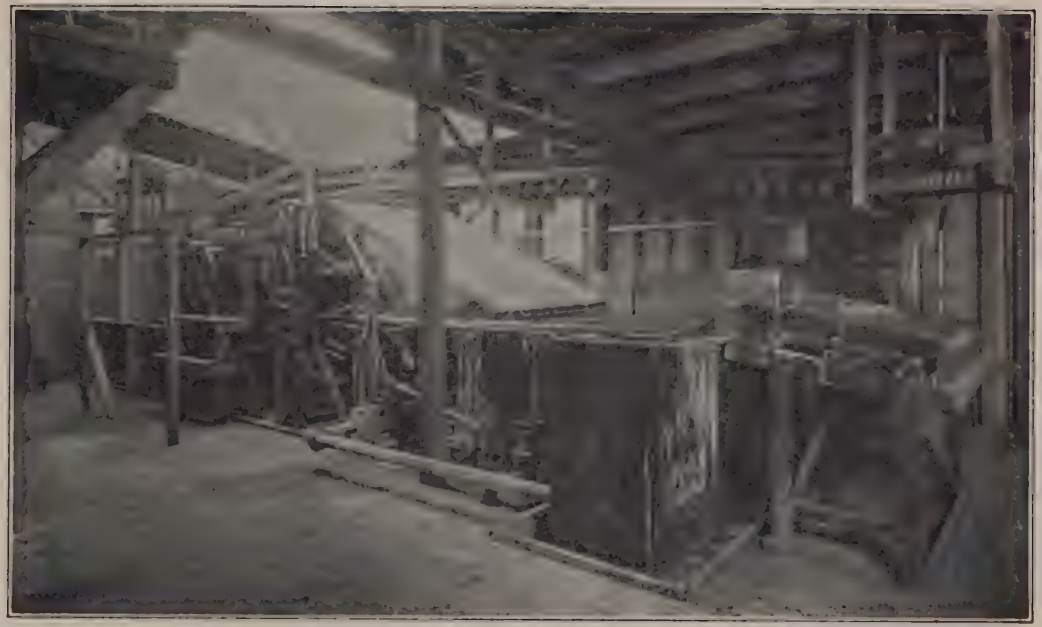

Fig. 7. A four runway Brogdexer and fruit cleaner as used for the 1927 crop at Wenkel, Washington. Photo from the Northwest Brogdex Co., Yakima, Washington.

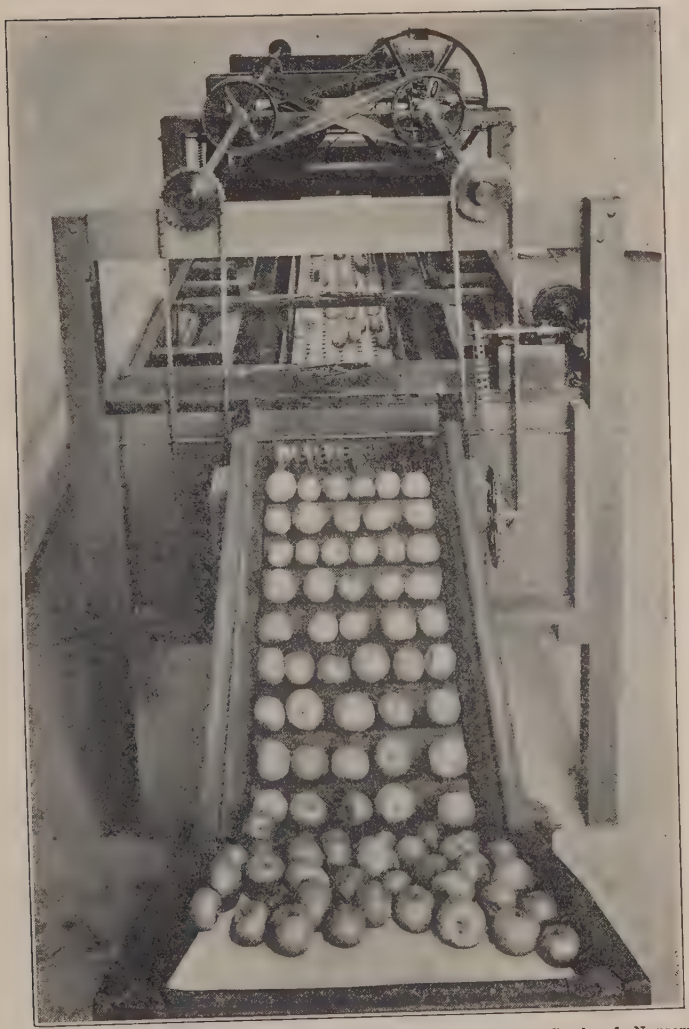

Fig. 8. The Ideal Washer and Sterilizer as made by the Ideal Grader & Nursery Co., Hood River, Oregon. Photo from the Company.

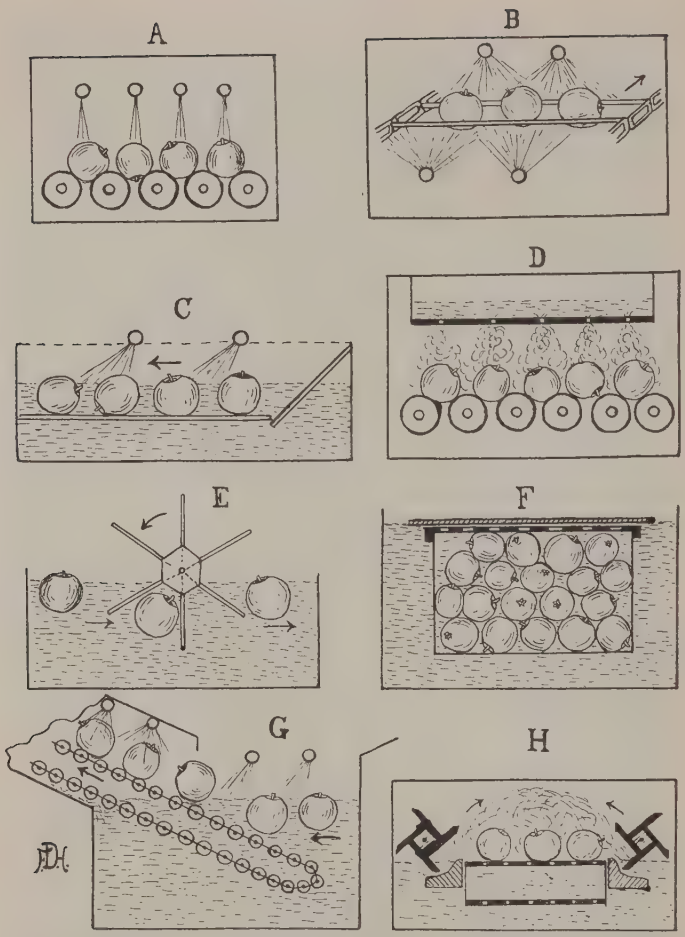

Fig. 9. Diagrammatic sections to show the method of application of the cleaning solution and the movement of the fruit through the machines for the different wet processes. A, the jet type of spray (Cutler); B, the fan type of spray (Bean); C, the flotation and spray (Stebler Parker); D, the flood wash (Andy Moe); E, the flotation dip type (American Fruit Growers); F, the box dip (Cashmere Fruit Growers); G, the flotation and spray (alkali, Brogdex Co.); H, the impeller flooding (Ideal Grader & Nursery Co.). For explanation of method of carrying the fruit through the cleaning compartment see chart, p. 23.

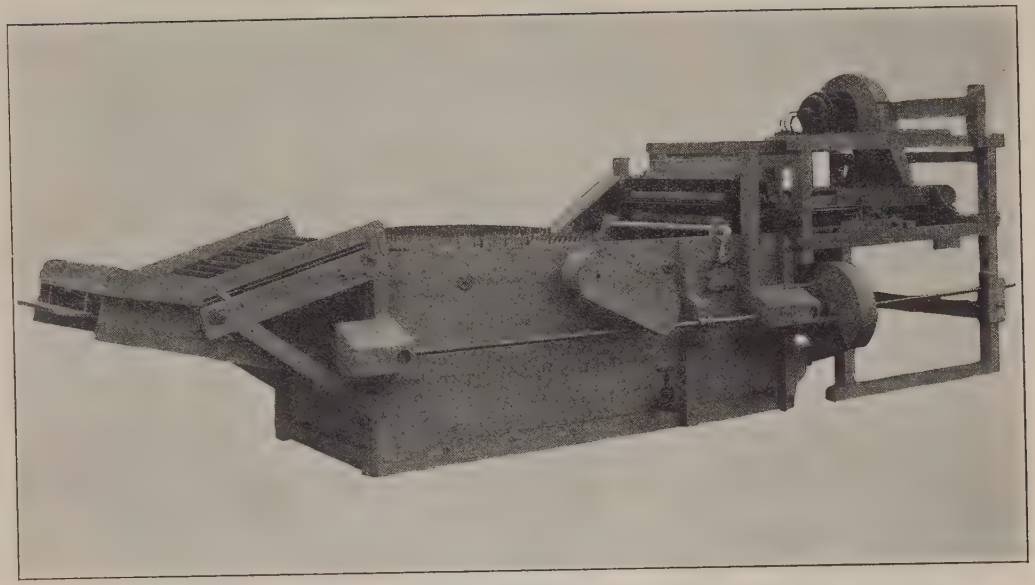

Fig. 10. The White Fruit Washer designed by E. A. White, Lewiston, Ida. Photo from E. A. White.

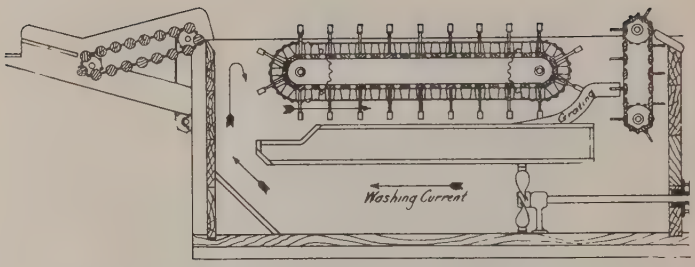

Fig. 11. Diagrammatic section to show method of application of the cleaning solution and the movement of the fruit through the stream wash machine (White). Diagram from E. A. White.

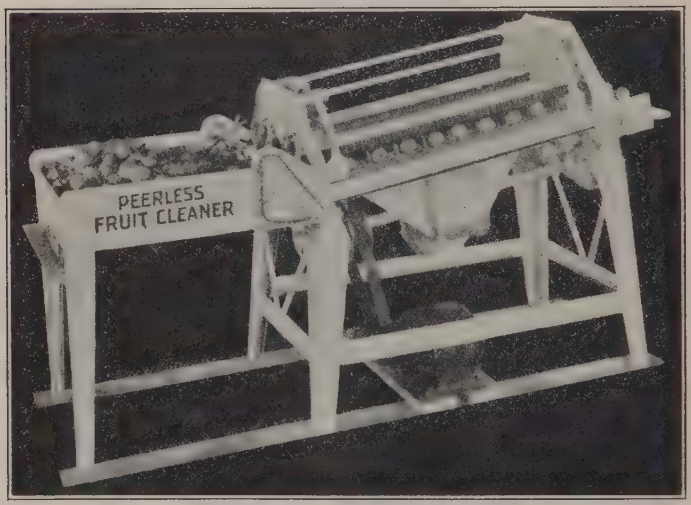

Fig. 12. The Peerless Vibrating Fruit Cleaner, manufactured by the Carter Mayhew Manufacturing Co, Minneapolis, Minn. Photo from the Company.

Fig. 13. Hemp brush dry wiper as used on the Sampson ranch, Wenatchee, Wash. Photo by Simmer Studio.

selected for the treatment of the experimental lots of fruit. In the Brogdite-Brogdex machine no regular dryer is used, but the apples pass to the rotating brushes which drive off the moisture and apply a thin coating of Brogdex (oil and paraffin).

Dry Wipers

Altho the experience of the 1926 packing season had shown the limitations of dry wiping in the removal of arsenical residue it seemed advisable to include tests with some of the dry wipers for comparison with the wet processes, both from effectiveness in residue removal and also from their relation to the incidence of decay. The following is a list of the dry wipers used:

1. The Peerless, Carter Mayhew Manufacturing Co., Minneapolis, Minn.
2. The Ideal, Ideal Grader & Nursery Co., Hood River, Ore.
3. Rotating Hemp Brush, Homemade machine used on the Sampson ranch, Wenatchee, Wash.
4. Andy Moe Wiper, Moe Iron Works, Toppenish, Wash.
5. Fruit Brusher "Supreme", Stebler Parker Co., Riverside, Cal.

All of these machines except No. 3 were described and illustrated in the bulletin from the Washington Agricultural Experiment Station issued March, 1927 (12) and the data given in that publication will not be repeated. The Peerless which has proved to be the most effective dry-wiping machine was entirely remodeled and is therefore presented in its newer form (Fig. 12). The rotating hemp brush is quite similar in principle to the Ideal and should be well understood by reference to the illustration (Fig. 13).

No attempt will be made to enter into a discussion of the the merits of the various machines from the standpoint of their mechanical operation. It should, however, be emphasized that the handling of fruit in such a way as to guard against mechanical injury is one of the most important considerations. Some of the machines are much more likely to cause mechanical injury than others, but a machine that is inherently safe may cause trouble in the hands of a careless operator.

Descriptive Chart of Wet Process Machines Used for the Crop of 1927

Name of machine	Descriptive Name	How cleaning solution is applied	Time of action of cleaning solution	Pressure	Method of carrying fruit through cleaning compartment	Turning of fruit	Type of rinse	Dryer
Cutler	Jet spray	Driving jets from circular openings in overhead pipes	20 sec.	+	Spiral roller conveyors	Continuously turning	Repumped and fresh water	Towel dryer & Andy Moe wiper
Bean	Fan spray	Fan-shaped spray from transverse slots in pipes above and below carrier	30 sec.	+	Carrier belt of rubber covered transverse rods	No turning	Repumped and fresh water	Driving air blast from above and below
Stebler-Parker	Flotation & spray	Flotation in tank with jet spray from overhead pipes	1-3 min.	+	Flotation and obliquely directed spray	Some turning by spray	Fresh water	Air blast from above and Andy Moe wiper
Andy Moe	Flood wash	Flooding from slits in overhead distributing chamber	40 sec.	None	Spiral rubber-covered roller conveyors	Continuously turning	Repumped and fresh water	Andy Moe dry wiper (rag or brush)
Orange Washer type	Flotation & dip	Flotation in tank	5-6 min.	None	Flotation and submerger paddles (ten) or paddle wheels	Some turning by 10 submergers	Fresh water	Andy Moe brush wiper
Box washer		By immersion of picking boxes	1 min. 45 sec. or 2 min.	None	Contact of boxes with overhead moving belt	No turning	Tank of fresh water and fresh water spray	Allowed to stand in boxes
Brogdex	Flotation & spray (alkali)	Flotation in tank with spray from overhead pipes while in tank and during passage up the elevator	1 min.	+	Flotation first then by roller elevator	Very little turning	Fresh water spray	Brush action & oil replacement
Ideal	Impeller flood wash	Flooding from rotating paddle-impellers	20 sec. to 5 min.	None	Series of 2-inch belts spaced by wooden cross cleats, thus making an open endless belt	Little or no turning	Same method as for cleaning solution	Ideal brush
White	Stream wash	By stream flowing same direction as fruit but much faster by action of rapidly revolving propeller	45 sec. to 1½ min.	None	Peg retarders on endless belt, holding fruit below surface, but moving slower than the current	Gentle shifting	Same method as for acid bath with inflow of fresh water—final spray of fresh water	Heavy air blast

THE EFFECTIVENESS OF THE VARIOUS PROCESSES AND MACHINES IN THE REMOVAL OF ARSENICAL RESIDUE

It has been pointed out that the ultimate aim of the fruit industry is to put the apple and pear crop on the market with a freedom from arsenic that will meet the world tolerance of .01 grains per pound of fruit. The perfection of machines that will accomplish this end is vital to the industry, consequently, our efforts were directed first to the testing of the various processes and machines that were available during the 1927 packing season. The consideration of the relation of the cleaning methods to the storage behavior of apples is a natural accompaniment of the work on residue removal and will be treated in the following main division of the bulletin.

Methods of Sampling, Cleaning and Analyzing the Fruit

Samples were selected from those orchardists from whom it was possible to obtain an accurate spray history of the fruit. This involved such questions as, amount and kind of spray, number of sprays, time of each application and the interval between last spray and time of harvest.

Each lot of fruit was obtained as soon as harvested, all of a medium uniform size, and in sufficient amounts to provide chemical and storage samples after dividing into sub-lots for the various cleaning processes.

In most cases a study was made of seven wet and four dry-cleaning processes, the names and characteristics of which have been tabulated and discussed above. These represented practically all of the processes in commercial operation. All except one of the wet processes used hydrochloric acid cleaning solutions, the acid strengths ranging from 0.2 to 0.4 per cent by weight for most of the season. For the late-season varieties that tended to become waxy the acid strength was increased to about 0.6 per cent. One wet cleaning process used an alkaline bath of sodium carbonate to which sodium hydroxide was added in some cases.

As soon as possible after harvest, in most cases within one or two days, portions of a given lot of fruit were subjected to each of the cleaning processes. All treated lots for a given set were held in the packing house until the set was completed when all were then put into storage at the same time. The treatment of the fruit through the harvesting, cleaning, packing and storing operations was strictly comparable to commercial practices. In fact the work was all done, under direction, by commercially operating labor and equipment.

For the determination of arsenical residue two samples of six fruits each were selected at random. These were subjected to boiling dilute hydrochloric acid and the arsenic thus obtained in the solution was determined by the improved Gutzeit method. From time to time and when starting with another variety of fruit, the dipping method of arsenical removal for chemical determination was checked against the peeling-digestion method. It was found that the dipping method removed all of the arsenic present except in a few cases where the fruit was very waxy. In such cases the dipping method was effectively modified by using a solution of boiling sodium hydroxide instead of hydrochloric acid.

Relation of Number of Cover Sprays to Effectiveness of Cleaning Processes

Effective control of codling moth is accomplished in some of the apple-producing sections of Washington by the use of but one cover spray of lead arsenate. These are the upper valley regions where the elevation is higher and the temperature cooler. With a decrease in elevation the codling moth infestation becomes more difficult to control, making it necessary to use a larger number of cover sprays.

It is obvious that fruit sprayed once only should not require so drastic a cleaning as fruit with several cover sprays. A study of this question was made by collecting Jonathan apples from different regions to give a series of lots that had received from one to seven cover sprays. The dry-cleaning processes were sufficient to clean

Table 1. Cleaning Effectiveness of Wet and Dry Process Machines upon Jonathan Apples That Had Received from One to Seven Cover Sprays

Cleaning processes	Calyx plus 1 cover 3-100	Calyx plus 2 covers 2-100	Calyx plus 3 covers 2½-100	Calyx plus 4 covers 2-100	Calyx plus 5 covers 2-100	Calyx plus 6 covers 2-100	Calyx plus 7 covers 2-100	Calyx plus 5 covers 4-100
Check	.0043	.0023	.024	.026	.023	.032	.028	.034
Jet spray	——	——	.010	.0046	.0065	.0065	.0055	.0087
Fan spray	——	——	.011	.0057	.0034	.0077	.012	.029
Flotation and spray	——	——	.011	.0067	.0083	.0065	.0063	.018
Flood wash	——	——	.011	.0063	.011	.013	.010	.017
Flotation and dip	——	——	.0086	.013	.0093	.011	.016	.027
Box dip	——	——	.0099	.011	.0088	.013	.011	.022
Flotation and spray (alkali)	——	——	.012	.0067	.013	.011	.0055	.015
Average of wet process			.011	.0077	.0086	.0089	.0095	.020
Vibrating bristle brushes	.0085	.0033	.017	.016	.016	.022	.021	.025
Rotating bristle brushes	.0059	.0025	.017	——	.020	.030	.011	.035
Rotating hemp brushes	.0038	.0034	.018	——	.024	——	.012	.039
Rag wiper	——	.0025	——	.027	——	——	016	——
Average of dry processes	.0061	.0029	.017	.021	.020	.026	.015	.033

the fruit well below the world tolerance of 0.1 grains As_2O_3 per pound in the case of the one-cover or two-cover lots obtained for this study.

It may be observed (Table 1) that in some cases the arsenical load of the dry-cleaned fruit is slightly greater than that on the uncleaned fruit as shown by the checks. This anomaly was largely due to the great variation in samples with reference to the arsenical load. This point was discussed at length in a previous publication (12). Since the check analyses do not represent more than two samples of six apples each, they are merely indicative of the approximate arsenical load carried by the uncleaned fruit. This statement holds for all the tabulations in this bulletin dealing with

chemical determinations of spray residue. The results given for cleaned fruit are much more indicative of the true average arsenical load for two reasons: one being that well-cleaned individual fruits carry much smaller and hence more uniform arsenical residue loads than is true of uncleaned fruits; the second reason for more uniformity is that portions of the same lots of fruit were subjected to several cleaning processes and the average result or these more nearly represents the effect of cleaning as related to type of spray, variety of fruit, time of cleaning, etc., than the result of any one individual process.

Refering again to Table 1 it may be noted that where three covers or more were used, the commercial wet-cleaning processes were on the average none too effective in removing sufficient of the residue to meet the world tolerance of .01 grains of As_2O_3 per pound of fruit. The average of the seven wet processes shows that the three-cover-spray lot was slightly more difficult to clean that the 4, 5, 6, and 7 cover lots. One reason for this result is probably due to the normal variation that exists between fruits from different orchards as caused by such factors as thoroughness of spraying, brand of lead arsenate, etc.

In general the results from this series of samples indicate that dry-cleaning processes cannot be considered safe with reference to the world or international tolerance where more than two covers have been used.

The last column of Table 1 shows that doubling the amount of lead arsenate used in the spray had a greater effect than increasing the number of cover sprays from three to as high as seven in number. This conclusion is likewise only indicative as it is based upon only one set of samples for one season.

Effectiveness of Cleaning Processes upon Apples Receiving a Normal or Average Spray

Form comparison purposes ten varieties of apples that had received a spray schedule consisting of from four to six covers of lead arsenate used at the rate of 2 pounds per 100 gallons are

Table 2. Removal of Aresnical Residue with Wet and Dry Process Machines Using Ten Varieties of Apples That Received a Normal Spraying

Cleaning processes	Winter Banana 4 covers 2-100	King David 4 covers 2-100	Grimes Golden 6 covers 2-100	Jonathans 5 covers 2-100	Delicious 6 covers 2-100	Spitenberg 5 covers 2-100	Rome 5 covers 2-100	Arkansas Black 5 covers 2-100	Winesap 6 covers 2-100	Stayman Winesap 6 covers 2-100
Check	.020	.019	.058	.023	.022	.029	.023	.017	.023	.015
Jet spray	.0036	.0011	.0071	.0065	.014	.0095	.0070	.0063	.011	—
Fan spray	.0035	.0053	.0093	.0034	.0072	014	—	.010	.015	.013
Flotation & spray	—	.0018	.0065	.0072	.0083	.0066	.0058	—	.0053	—
Flood wash	.0033	—	.0098	.011	—	.011	.0052	.0070	—	—
Flotation & dip	.0057	.0061	.015	.0093	.016	.021	.016	.0063	.013	—
Box dip	.0035	—	.013	.0088	.019	014	.0027	.014	.011	—
Flotation spray (alkali)	—	—	.0090	.013	.013	.011	.0086	.0043	.0051	.0043
Average for wet processes	.0039	.00	.010	.0085	.013	.012	.083	.0080	.010	.0087
Vibrating bristle br.	.0078	.010	.026	.017	.016	.023	.014	.011	.017	.012
Rotating br. brushes	0086	—	.027	.020	.020	.021	.018	—	.016	—
Rotating hair brush	—	—	—	—	—	—	.0098	—	—	—
Rag wiper	—	—	—	—	—	.022	.015	—	—	—
Rotating hemp br.	—	—	.026	.017	.024	.028	.024	—	.022	—
Average for process	.0082		.026	.018	.020	.024	.016		.018	

Below International Tolerance—39 lots or 42.0 per cent.
Below 1927 Domestic Tolerance—89 lots or 95.7 per cent.
Above 1927 Domestic Tolerance—4 lots or 4.3 per cent. (all dry cleaning)

listed in Table 2. Duplicate lots of these fruits were subjected to seven wet and five dry-process machines. It may be noted that, on the average, the wet processes caused a reduction to or below .01 grains of As_2O_3 per pound for all of the ten varieties except Delicious and Spitzenberg. The dry processes reduced the arsenical load to .01 grains per pound on the Winter Banana variety only.

Table 3. Results of Cleaning Different Varieties That Received Special Sprays Resulting in Large Aresnical Loads—to be Compared with Normal Sprays of Same Varieties in Table 2.

Cleaning processes	Jonathan		Spitzenberg		Rome *	Winesap
	5 covers 4-100	5 covers 2-100 plus oil	5 covers 4-100	5 covers 2-100 plus fish oil	5 covers 2-100	5 covers 2-100 plus fish oil
Check	.034	.074	.038	.042	.041	.037
Jet spray	.0078	.015	.013	.029	.020	.012
Fan spray	.029	.023	.019	.013	.023	.013
Flotation & spray	.018	.0061	——	.012	.015	.0079
Flood wash	.017	.029	——	.021	.019	.010
Flotation & dip	.027	.022	——	.031	.018	——
Box dip	.022	.031	.020	.030	.032	.014
Flotation & spray (alkali)	.015	.026	.015	.029	.018	.0097
Average for wet process	.020	.022	.017	.026	.021	.011
Vibrating bristle brushes	.025	.035		.040	——	.021
Rotating bristle brushes	.035	.052		.034	——	——
Rotating hemp brushes	.039	.053		.042	——	——
Rag wiper	——	——		.044	.034	——
Average for dry processes	.033	.047		.040		——

* The Rome apples were sprayed with a special iron-coated lead arsenate.

Of the total 89 lots of fruit thirty-nine or 42 per cent were cleaned to or below the world tolerance of .01 and eighty-nine lots or 95.7 per cent to or below the 1927 domestic tolerance of .025 grains per pound.

In Table 3 the data of six lots of fruit are listed, these being similar to the six lots of the same varieties of Table 2 except that the lead arsenate was used either in double strength or with additions of materials causing more of the lead arsenate to be retained on the fruit. As thus compared, as may be seen in Table 4, the amount of arsenical residue remaining after washing was much greater on the fruit that received special types of spray for Jonathan, Spitzenberg, and Rome, and was about the same for the Winesap.

Table 4. A Summary of Tables 2 and 3 to Show the Effect of Increasing the Amount of Lead Arsenate in Spray or of Adding Spreader or Oils to the Lead Arsenate

	Average arsenical load remaining on washed fruit in grains As_2O_3 per pound			Per cent of washed lots cleaned to the .01 tolerance		
	Jonathan	Rome	Winesap	Jonathan	Rome	Winesap
Standard (2-100 of lead arsenate)	.0085	.0083	.010	71.4	83.3	33.3
Special (lead in double strength or with additions)	0.21	.021	.011	14.3	00.0	50.0

Influence of Types of Spray upon the Effectiveness of Cleaning Processes

Jonathan—For a part of the study of types of spray upon the effectiveness of cleaning processes, fruit from a large block of Jonathan trees was obtained that had been sprayed in a uniform manner in so far as the number of covers, the time of application and the method of application were concerned.* It will be observed

* From the experimental orchard at Wenatchee. The fruit was furnished by Mr. Anthony Spuler.

Table 5. Effectiveness of Cleaning Processes upon Jonathans Sprayed with Different Amounts of Lead Aresnate with and without Additions of Oil and Spreader. (All of the lots received 5 cover sprays, were sprayed in the same orchard at the same periods and by similar methods. They were cleaned with acid of .33 per cent strength for all machines.)

Cleaning Processes	Grains As_2O_3 per pound							Average per cent removed
	Lead only 2-100	Lead 2-100 Spreader ½-100	Lead 2-100 Spreader 1-100	Lead only 4-100	Lead 4-100 Spreader ½-100	Lead and oil	Average	
Check	.023	.026	.038	.034	.075	.074	.045	
Jet spray	.0065	.0065	.0074	.0087	.014	.015	.0097	78.5
Fan spray	.0034	.0089	.013	.029	.023	.023	.017	62.2
Flotation and spray	.0072	.0082	.011	.018	.0071	.0061	.0096	78.7
Flood wash	.011	.012	.016	.017	.037	.029	.020	55.6
Flotation and dip	.0093	.012	.012	.027	.030	.022	.019	57.8
Box dip	.0088	.014	.012	.022	.036	.031	.021	53.3
Flotation spray (alkali)	.013	.013	.012	.015	.029	.026	.018	60.0
Average of washing processes	.0085	.011	.012	.020	.025	.022	.016	63.1
Vibrating bristle brushes	.017	.026	.024	.025	.052	.035	.031	33.3
Rotating bristle brushes	.020	.027	.030	.035	.070	.052	.039	13.3
Rotating hemp brushes	.017	.025	.017	.039	.053	.053	.034	24.4
Average for dry brushes	.018	.026	.024	.033	.058	.047	.034	24.4

that portions of six different lots of the fruit were cleaned by seven wet and three dry-cleaning processes. (Table 5)

Each of the six lots received a calyx spray and five cover sprays of orchard brand lead with and without additions of spreader or oil. Averaging the results for the seven cleaning processes for each type of spray it is apparent that .0085 grains of As_2O_3 remained

on the fruit that had been sprayed with lead arsenate at the rate of two pounds per 100 gallons of water. This lot was the only one of the six that was cleaned, on the average, to or below the world tolerance of .01 grains of As_2O_3 per pound.

When the lead arsenate was used at the rate of four instead of two pounds per 100 gallons the average load on the wet-cleaned fruit was .02 grains per pound. The use of one per cent of mineral oil in the second and third covers in addition to lead arsenate at the rate of 2 pounds per 100 gallons (last lot) resulted in about the same difficulty of removal as in the case of lead arsenate at 4 to 100. Results obtained with spreader in the lots of Table 5 indicate that the use of spreader did not cause the fruit to be more easily cleaned.

A study of the effectiveness of cleaning by dry wiping or brushing was also conducted with portions of the same lot upon which the wet-process tests were made. Averaging the results of three dry brush machines it may be seen that none of the Jonathans of Table 5 were cleaned below the world tolerance and only two of the lots averaged below the 1927 domestic tolerance of .025 grains per pound. In general the different types of spray appear to affect dry wiping in about the same way as has been discussed above for the wet-cleaning processes.

Although the same strength of acid was used in the various cleaning machines for these lots of Jonathans, too much importance should not be given to the order of effectiveness as given by the data in Table 5 since the fruit was subjected to the acid for different lengths of time varying from 20 seconds in the jet spray type to 5 minutes in the flotation and dip process.

Spitzenberg—Some Spitzenberg trees were sprayed in a similar manner in all respects except that spreader and oils were added to the spray in some cases as shown in Table 6.

One lot of these trees received a calyx and five cover sprays of lead arsenate only at the rate of two pounds per 100 gallons. Another lot received similar lead arsenate spraying but with the addition of one-half pound of calcium caseinate spreader. In these tests the

Table 6. Effectiveness of Cleaning Processes upon Spitzenberg Apples Sprayed with Different Types of Spray. (All of the lots received 5 cover sprays and were sprayed in the same orchard and by similar methods. Results given in grains As_2O_3 per pound of fruit.)

Cleaning processes	Type of Spray						Average lead remaining
	Lead only 2-100	Lead 2-100 plus spreader 1. 2-100	Lead 2-100 plus mineral oil	Lead 2-100 plus fish oil	Lead 2-100 and nicotine *	Lead only 4-100	
Check	.036	.029	.031	.042	.027	.038	.034
Jet spray	.012	.0095	.0069	.029	.0099	.013	.013
Fan spray	.0097	.014	.011	.031	.017	.019	.017
Flotation and spray	——	.0066	.0084	.012	.0081	——	.0088
Flood wash	——	.011	.0098	.021	.013	——	.014
Flotation and dip	.017	.021	.017	.031	.014	——	.020
Box dip	——	.014	.014	.030	.012	.020	.018
Flotation and spray (alkali)	——	.011	.015	.029	.012	.015	.016
Average of wet processes	——	.012	.012	.026	.012	——	.015
Vibrating bristle brushes	.033	.023	.021	.040	.018	——	——
Rotating bristle brushes	.023	.021	.027	.034	.015	——	——
Rotating hemp brushes	.024	.028	.023	.042	.020	——	——
Rag wiper	——	.022	.021	.044	.025	——	——
Average of dry processes	.027	.024	.025	.040	.020	——	.027

addition of the spreader had relatively little effect upon the efficiency of the cleaning processes used.

Table 6 also shows the result obtained when fish oil was added at the rate of one-fourth per cent to the lead arsenate spray. With this spray combination it may be seen that none of the wet-cleaning processes caused a reduction of the arsenical load to or below the world tolerance of .01 grains of As_2O_3 per pound of fruit.

It may be further noted that with this combination only two of the wet-cleaning processes attained a reduction to or below the 1927 domestic tolerance of .025 grains per pound.

In the lot where nicotine was used at the rate of one pint per six hundred gallons in the fourth and fifth covers without the lead arsenate, the arsenical residue remaining as shown by averaging the wet-cleaning processes was the same as that remaining in the case of the lot that received the spreader and the lot on which mineral oil was used (Table 6). It seems unusual that the lot sprayed with nicotine was not completely cleaned since it received two covers less of lead arsenate than the other lots listed in this table.

Where lead arsenate was applied at the rate of four pounds per 100 gallons or double the amount used in the previously mentioned lots, the residue remaining was above the world tolerance in each of the four cleaning processes studied. Thus with Spitzenberg apples as with Jonathans (Table 5) it is apparent that doubling the amount of lead arsenate makes it much more difficult to effect efficient removal down to the world tolerance of .01 grains per pound.

Four different types of dry-cleaning machines were studied in connection with the Spitzenberg apples discussed above. It may be seen (Table 6) that none of the lots were reduced to the world tolerance and that only twelve of the twenty lots were reduced to the .025 tolerance. These results for Spitzenberg apples are similar to those for Jonathan apples in Table 5 in showing that the wet processes were over twice as effective as the dry in the removal of arsenical residue.

Winesap—Winesap apples of the 1927 Wenatchee harvest sprayed with one calyx and five covers of lead arsenate at the rate of two pounds per 100 gallons were fairly easy to clean. All except one of the seven washing machines reduced the arsenical residue load below the tolerance of .01 grains of As_2O_3 per pound of fruit (Table 7). When fish oil was added only three of the washing processes reduced the arsenical load to the .01 tolerance. In both cases the vibrating brush cleaner caused a reduction well below the 1927 domestic tolerance of .025 grains per pound. In view of the results previously

obtained (12) it was apparent that Winesaps as well as other varieties of the 1927 harvest carried considerable smaller arsenical loads than was true of fruit from the same districts in 1926.

Table 7. Effects of Various Cleaning Processes Upon Removal of Arsenical Residue from Winesap, Rome, Arkansas Black, and Yellow Newtown Apples Sprayed in Different Ways as Shown

Cleaning processes	Winesap		Rome		Arkansas Black			Yellow Newtown	
	Lead only 2-100	Lead 2-100 plus fish oil	Lead only 2-100	Lead 2-100 plus cresoap	Lead only 2-100	Lead 2-100 plus fish oil	Lead and nicotine	Lead 2-100 plus spreader ½-100	Lead 2-100 plus mineral oil
Check	.024	.037	.023	.025	.017	.015	.017	.052	.039
Jet spray	.011	.012	.0070	.016	.0063	.0075	.011	.029	.017
Fan spray	.0092	.013	——	.0094	.010	.0078	.0065	.026	.016
Flotation and spray	.0061	.0079	.0058	.018	——	.0041	.0037	.010	.0065
Flood wash	.0071	.010	.0052	——	.0070	.0088	.0052	.016	.0088
Flotation and dip	.0062	.0068	.016	.0066	.0063	.0054	.0046	.021	——
Box dip	.0090	.014	.0072	.0093	.014	.014	.0063	.016	.020
Flotation and spray (alkali)	.0091	.0097	.0086	.0047	.0043	.0054	.0019	.016	.0082
Average of wet processes	.0082	.011	.0083	.011	.0080	.0079	.0059	.019	.013
Vibrating bristle brush	.012	.021	.014	——	.011	.0098	.0090	.033	——

Rome—When a normal lead arsenate spray of 5 covers of 2 pounds per 100 gallons was applied to Rome apple trees, five of the washing processes reduced the arsenical load below .01 grains of As_2O_3 per pound (Table 7). The addition of small amounts of cresoap to the spray did not appreciably affect the removal of the arsenical residue.

Arkansas Black—The Arkansas Black apples that were available for test carried light loads of residue as may be observed in Table 7. This was due in part to the large size of the apples. In practically every case the washing processes reduced the arsenical load on these apples to or below .01 grains per pound (Table 7). The addition of fish oil to the lead arsenate spray had little effect upon removal of

the arsenical load whereas it caused a considerable retention in the case of the Jonathan and Spitzenberg varieties.

Yellow Newtown—Unfortunately a series of samples of this variety was not obtained upon which lead arsenate only had been applied. In the lot where one-half pound of a caseinate spreader together with lead arsenate at the rate of 2 pounds per 100 gallons for five covers was used none of the washing processes effected a reduction to .01 grains per pound (Table 7). The use of mineral oil instead of spreader did not appreciably affect the results.

Comparative Effectiveness of the Cleaning Processes

Making use of the results obtained with the six varieties listed above in Tables 5, 6 and 7, the data of Tables 8 and 9 are compiled to

Table 8. The Per Cent of Lots of Various Varieties of Apples that Were Cleaned to or below 0.01 Grains of As_2O_3 per Pound by the Cleaning Methods as Listed

Cleaning processes	Varieties *					
	Jonathan	Yellow Newtown	Winesap	Spitzenberg	Arkansas Black	Rome
Jet spray	67	50	33	50	67	50
Fan spray	33	00	50	17	67	67
Flotation and spray	67	67	67	67	100	50
Flood wash	00	67	83	25	100	67
Flotation and dip	17	50	83	00	33	67
Box dip	17	00	33	00	33	67
Flotation and spray (alkali)	00	67	100	00	100	50
Average for wet processes	28.7	43.0	64.1	22.7	71.4	59.7
Vibrating bristle brushes	00	00	00	00	67	00
Rotating bristle brushes	00	—	—	00	—	—
Rag wiper	—	—	—	00	—	00

* The spray treatments and lots are given in Tables 5, 6 and 7.

show the relative effectiveness of each cleaning process, in terms of the per cent of lots that were cleaned to or below the .01 and .025 units of grains As_2O_3 per pound. In considering these tables it should be borne in mind that the various lots were subjected to the cleaning processes as they were found in commercial operation and that the processes are not strictly comparable because of variations in acid strengths and times of treatment with the different machines.

Table 9. The Per Cent of Lots of Various Varieties of Apples That Were Cleaned to or Below 0.25 Grains of As_2O_3 per Pound of Fruit by the Cleaning Methods as Listed

Cleaning process	Varieties *					
	Jonathan	Spitzenberg	Rome	Winesap	Arkansas Black	Yellow Newtown
Jet spray	100	83	100	100	100	50
Fan spray	83	83	100	100	100	67
Flotation and spray	100	100	100	100	100	100
Flood wash	67	100	100	100	100	100
Flotation and dip	67	80	100	100	100	50
Box dip	67	80	67	100	100	100
Flotation and spray (alkali)	67	80	100	100	100	100
Average for wet processes	78.7	86.6	95.3	100.0	100.0	81.0
Vibrating bristle brushes	70	60	67	100	100	67
Rotating bristle brushes	17	60	—	—	—	—
Rag wiper	—	50	67	—	—	—

* The spray treatments and lots are given in Tables 5, 6 and 7.

For the purpose of comparing varieties with reference to world and 1927 domestic tolerance limits the columns of averages in Tables 8 and 9 are placed in Table 10. As may be observed in Tables 5, 6 and 7 various types of sprays were used on the varieties listed in Table 10. For that reason the varieties listed in Table 10 can not be compared with reference to relative difficulty of cleaning.

Table 10. A Summary of the Data of Tables 8 and 9 Giving, for Each Variety, the Per Cent of Samples Cleaned Below .01 and.025 Grains Respectively of As_2O_3 per Pound of Fruit as Obtained by Averaging the Results of All Washing Processes

Variety	Per cent of samples cleaned to or below		Per cent above
	.01 grains As_2O_3 per pound	.025 grains As_2O_3 per pound	.025 grains As_2O_3 per pound
Jonathan	28.7	78.7	21.3
Spitzenberg	22.7	86.6	13.4
Yellow Newtown	43.0	81.0	19.0
Winesap	64.1	100.0	none
Arkansas Black	71.4	100.0	none
Rome	59.7	95.3	4.7
Average	48.3	90.3	9.7

Averaging all of the results obtained with these varieties it may be seen (Table 10) that 48.3 per cent of the lots were cleaned to or below the .01 and 90.3 per cent to or below the .025 tolerance respectively, leaving 9.7 per cent of the washed fruit that carried more than .025 grains per pound of As_2O_3.

Table 11. Removal of Aresnical Residue from Various Varieties of Apples Using Various Cleaning Processes

Cleaning processes	No. of lots of fruit	Grains of As_2O_3 per pound	
		Range	Average amount remaining
Check	34	.015 -.075	.032
Jet spray	31	.0011-.029	.010
Fan spray	33	.0034-.029	.013
Flotation and spray	30	.0018-.018	.0079
Gravity flood wash	27	.0033-.027	.013
Flotation and dip	30	.0011-.031	.013
Box dip	31	.0056-.032	.015
Flotation and spray (alkali)	31	.0019-.029	.012
Vibrating bristle brushes	33	.0078-.052	.021
Rotating bristle brushes	22	.0086-.070	.025
Rotating hemp brushes	18	.012 -.053	.027
Rag wiper	13	.0070-.044	.023

Varieties included in above: Winter Banana, King David, Grimes Golden, Jonathan, Delicious, Spitzenberg, Rome, Stayman, Winesap, Arkansas Black, and Yellow Newtown.

In addition to the six varieties discussed above, cleaning studies were made on Winter Banana, King David, Grimes Golden, Delicious and Stayman Winesap varieties. Results for all of the varieties are given in Table 11 which shows for each cleaning process the number of lots of fruit used and the range of residue loads remaining. It may be observed that from 20 to 30 lots were used for each wet-cleaning process. As discussed above these lots represent a variety of different types of sprays. Furthermore the apples were subjected to cleaning processes operating under commercial conditions with different strengths of acid and different periods of treatment. For these reasons a strict comparison should not be made of the relative efficiency of the various machines. Since Table 11 gives a record of the amount of cleaning obtained with the principle varieties of apples it may be considered to represent a cross section of the amount of cleaning efficiency for the 1927 season as related to the .01 and .025 tolerances.

Factors Affecting the Efficiency of the Washing Processes

In addition to the several factors that affect the ease of cleaning the arsenical residue from the fruit as discussed above, there are various factors of importance that may be altered or controlled for any given washing process. Among these are strength of acid or alkali, time of treatment, temperature of cleaning solution and method of making contact between the solution and the fruit.

For the purpose of studying the effect of altering some of these factors a large number of lots of fruit were run through a Bean washer which, as set forth above, employs the principle of the action of fan-like sprays of acid upon the non-rotating fruit.

For the first of these special studies Winesap apples were used that had received a spray of one calyx and six covers consisting of lead arsenate at the rate of 2 pounds per 100 gallons. As may be seen in Table 12 three strengths of acid were used, three lengths of treatments and two sets of pipes. For half of the samples, double the number of spray pipes were used which resulted in double the amount of sprayed liquid at about half the pressure at the point

of outlet. The results show quite distinctly that for this lot of fruit, with the washing solution at 52° F., a variation in the number of pipes was without effect; nor was there any significant effect due to changing the time of treatment from 30 to 90 seconds except where the acid was increased to 1.16 per cent by weight. It should be pointed out that this lot of Winesap apples as well as those discussed below (Lots 2 and 3) were quite waxy when subjected to the cleaning process as they had been in cold storage for over a month.

Table 12. Winesaps (Lot 1). Cleaned by Fan Spray Machine with Variations in Strength of Acid, Time of Treatment and Number of Pipes. Treatments Made at 52° F.

Per cent acid by weight	Length of treatment in seconds	No. of spray pipes	As_2O_3 remaining grains per pound	Average grains As_2O_3 per pound for			
				Time of treatment	Regular pipes	Extra pipes	Given acid strength
.55	30	Regular	.0075				
		Extra	.0098	.0087			
	70	Regular	.0072				
		Extra	.0065	.0069			
	90	Regular	.0064				
		Extra	.0074	.0067	.0070	.0079	.0075
.88	30	Regular	.0085				
		Extra	.0064	.0075			
	70	Regular	.0089				
		Extra	.0086	.0088			
	90	Regular	.0088				
		Extra	.0078	.0083	.0087	.0076	.0082
1.16	30	Regular	.0062				
		Extra	.0081	.0072			
	70	Regular	.0071				
		Extra	.0048	.0060			
	90	Regular	.0041				
		Extra	.0041	.0041	.0058	.0057	.0058
Check untreated			.024				

Spray schedule—Lead arsenate. 2-100, calyx and 6 covers.

Using a second lot of Winesaps that were considerably harder to clean at harvest time a study was made of the effect of changing the above mentioned factors. The treatments were made at 48° F. and the results with this lot of fruit (Table 13) show the following

points: first, that changing the number of spray pipes and thus increasing the volume of spray and reducing the pressure had only a slight effect upon the amount of removal of arsenical residue; second, that varying the acid strengths between the limits of one and two per cent by weight produced no change; third, that only a slight change occurred when the time of treatment was made as much as four hours longer.

Table 13. Winesaps (Lot 2) Cleaned by Fan Spray Machine with Variations of Acid, Time of Treatment and Number of Pipes. Treatment Made at 48° F.

Per cent acid by weight	Length of treatments in seconds	Pressure of spray	As_2O_3 remaining grains per pound	Average grains As_2O_3 per pound for		
				Time of treatment	Single pipes	Double pipes	Given acid strength
1.00	32	High	.018				
		Low	.021	.020			
	55	High	.019				
		Low	.017	.018			
	140	High	.017				
		Low	.014	.016	.017	.017	.017
1.33	32	High	.024				
		Low	.021	.023			
	55	High	.023				
		Low	.012	.018			
	140	High	.016				
		Low	.015	.016	.021	.016	.019
1.66	32	High	.020				
		Low	.011	.016			
	55	High	.017				
		Low	.019	.018			
	140	High	.014				
		Low	.019	.017	.019	.016	.018
2.00	32	High	.017				
		Low	.025	.021			
	55	High	.014				
		Low	.024	.019			
	140	High	.016				
		Low	.010	.013	.016	.020	.018
Check untreated			.039				

Spray schedule—Naco lead 3-100, calyx and first covers, last 3 covers, 2½-100 plus ½-100 Naco Spreader.

Table 14. Effect of Varying the Acid Strength, Time of Treatment, and Number of Spray Pipes on Cleaning Effect of Fan Spray Machine upon Arkansas Black Apples. Treatments Made at 52° F.

Per cent acid by weight	Length of treatment in seconds	Number of spray pipes	As_2O_3 remaining in grains per pound	Average grains As_2O_3 per pound for			
				Time of treatment	Regular pipes	Extra pipes	Given acid strength
.54	30	Regular	.014				
.54	30	Extra	.012	.013			
.54	70	Regular	.0085				
.54	70	Extra	.012	.010			
.54	90	Regular	.0072				
.54	90	Extra	.010	.0086	.0099	.011	.011
.88	30	Regular	.010				
.88	30	Extra	.0092	.0096			
.85	70	Regular	.0080				
.85	70	Extra	.011	.0095			
.86	90	Regular	.0077				
.86	90	Extra	.011	.0094	.0086	.010	.0095
1.16	30	Regular	.0083				
1.16	30	Extra	.0068	.0076			
1.10	70	Regular	.0073				
1.10	70	Extra	.0075	.0074			
1.10	90	Regular	.010				
1.10	90	Extra	.011	.011	.0085	.0085	.0085
Check untreated			.022				

The slight effect of varying the acid strength, time of treatment and number of pipes with the solution at a temperature of 52° F. is shown in results obtained with Arkansas Black apples (Table 14).

Pentzer, Moore, Palmer and Daughters (21) found that at a temperature of 50° F. an increase in acid strength resulted in an increased amount of removal. They also found that time of treatment had a greater influence than that given in the results shown in Tables 12, 13 and 14. The fruit that they used carried about .10 grains of arsenic as As_2O_3 per pound, which was about three times as much as the load on the fruit used in the results here reported. This may account for their more pronounced findings regarding strength of acid and time of treatment as it is known that the major part of heavy arsenical residue loads are more easily removed than a corresponding percentage of lighter loads.

Further work with the stored Winesaps (Lot 2) tended to show that when the solution was heated to a temperature of 95 to 100° F. considerably more of the arsenical spray residue was removed than was possible at a temperature of 44 to 49° F. (Table 15). At the higher temperatures increasing the strength of the acid by over three times starting at .29 per cent, did not cause much of a change in cleaning effectiveness. At the 44-49° F. range similar results were obtained with one per cent as with two per cent acid.

Table 15. Effects of Variations of Strength of Acid, Time of Treatment and Temperatures of Acid Solution upon Cleaning of Oil and Lead Aresnate Sprayed Winesap Apples (Lot 2) Using a Fan Spray Machine

Per cent acid by weight	Temperature of solution in °F.	Time of treatment in seconds	As_2O_3 grains per pound remaining	As_2O_3 average for	
				95-100° range	44-49° range
0.29	95	55	.010		
0.50	99	55	.0092		
0.75	100	55	.010		.0097
1.00	97	32	.016		
1.00	97	55	.013		
1.00	49	32	.023		
1.00	49	55	.018		
1.00	49	150	.024	.022	.015
1.33	44—49	32	.021		
1.33	44—49	55	.024		
1.33	44—49	140	.020		
1.66	44—49	55	.025		
1.66	44—49	140	.025		
2.00	44—49	140	.019	.021	
Average				.022	.014
Check untreated			.039		

Spray schedule as per Table 13.

Using a third lot of Winesap apples a further study was made of the effect of changing the temperature and strength of the acid cleaning solution. The results (Table 16) show that at 45° F. the acid was only slightly more effective in concentrations ranging from one up to three per cent. At a treatment temperature of 70-75° F. the

more concentrated acid solutions were somewhat more effective. At a treatment temperature of 95-98°F. increasing the acid strength was also somewhat effective. When the temperature ranges are averaged it is apparent that an increase in temperature is distinctly effective in causing more complete arsenical residue removal. The fact that that average result of .0084 grains of As_2O_3 per pound of fruit, obtained at 45°F., was with considerably stronger acid solutions than the average of .0058 grains per pound, obtained at 95° to 98° F., again demonstrates that temperature is the effective causative factor in the attainment of efficient cleaning.

Table 16. Effects of Variations of Concentrations and of Temperature of Acid as Related to the Removal of Lead Arsenate from Winesap Apples (Lot 3) Using a Fan Spray Machine

Per cent of acid by weight	Temperature of acid in °F.	As_2O_3 remaining grains per pound	Average As_2O_3 for each temp. range
1.1	45	.010	For 45°F.
1.4	45	.0091	
1.6	45	.0089	
1.9	45	.0070	
2.3	45	.0090	
2.7	45	.0087	
3.0	45	.0062	.0084
.4	71	.010	For 70 to 75°F.
.7	75	.0085	
1.0	77	.0063	
1.4	70	.0058	.0077
.4	95	.0074	For 95 to 98°F.
.7	95	.0052	
1.0	98	.0041	
1.3	95	.0064	.0058
Check untreated		.023	

Spray schedule—Corona lead, 2-100, calyx and five covers.

Moreover, it is apparent that for these lots of fruit the temperature of the acid solution needed to be around 95° F. before an appreciable effect was obtained (Table 16). At 90° to 100° F. the waxy coating on apples begins to soften to a considerable extent. It is probable that the beneficial effect of increasing the temperature of the solution

is to soften the wax and permit better contact between acid and lead arsenate. Increasing the temperature of the acid also causes it to be more active chemically but in view of the slight effect shown above, of the large increases in acid concentration at temperatures below 95°F., it would seem that the main result obtained with high temperatures is to soften the wax sufficiently for the acid to get at the lead arsenate.

The maintenance of high solution temperatures requires considerable heating because of the heat loss to the cold fruit that is constantly being introduced; because of losses due to the latent heat of evaporation which may be considerable in a spray cleaning system; and because of radiation of heat from the treating machine. Proper insulation and checking of evaporation should aid in maintaining temperatures high enough to effect a sufficient cleaning of the fruit.

With the best of equipment, however, the maintenance of a warm cleaning liquid entails added labor and expense. It can be largely avoided by cleaning the fruit as promptly as possible after harvest before excessive amounts of wax have accumulated. Before the fruit becomes waxy, the cleaning process is easier and a weaker cleaning solution or a shorter treatment time may then be used. Fruit that is stored before cleaning may become very difficult to clean even with strong acid solutions and long treatment periods as shown in the results given above with stored Winesap and Arkansas Black apples.

Effect upon Cleaning of Reducing the Pressure in a Jet Spray Machine

As shown above the efficiency of the fan-spray process was about the same with a normal number of pipes as with double the number resulting in a consequent doubling of the number of sprays, at about half the pressure at the point of outlet.

In the jet-spray type of machine the cleaning liquid strikes the surface of the fruit with greater velocity than is true of the fan-spray type, although in both cases the liquid pressures in the spray pipes may be the same. This is because the liquid particles of the jet spray

are forced upon the fruit in a compact mass, whereas, when the liquid leaves the pipe in a narrow fan-like spray, air resistance breaks it up into fine droplets, the velocities of which are much slowed down before reaching the surface of the fruit.

Since the efficiency of spray cleaning processes may be considered to depend to some degree upon the force with which the cleaning liquid strikes the fruit the above discussion may serve to explain why a reduction of pressure causes a reduction of cleaning for the jet process machine (Table 17). This reduction of pressure was brought about by directing the jet sprays upward against the cover of the machine, causing the liquid particles to be broken up and to lose a large part of their force as they fell back on the surface of the fruit.

Table 17. Effect upon Arsenical Removal from Apples of Reducing the Velocity of the Cleaning Liquid in the Jet Spray Process

Variety	Grains As_2O_3 per pound of fruit		
	Checks	Normal pressure	Reduced pressure
Jonathan	.072	.022	.036
Winesap	.049	.014	.018
Yellow Newtown	.072	.012	.028

Effect of Holding Apples in Cold Storage Before Cleaning

At harvest time portions of the Jonathan, Delicious and Winesap lots of apples were put, uncleaned, into cold storage for the purpose of making delayed storage cleaning tests. These tests were made February first after the fruit had been in storage about four months.

The Bean machine was used which, as above described, employs principle of a fan-like spray of hydrochloric acid forced out of pipes placed above and below the non-rotating fruit. As may be seen in Table 18, the fruit carried after cleaning on February first, slightly higher arsenical residues than that which was cleaned at harvest time.

The cleaning of February first was conducted with .44 per cent acid at a temperature of 84 degrees F. while on the lots cleaned at the time of harvest somewhat weaker acid solutions and lower temperatures were used.

On March 7 some Spitzenberg and Winesap apples were taken from cold storage and subjected to the cleaning process of White's machine, the principles of which are described above.

Table 18. Comparison of Efficiency of Fan Spray Process upon Portions of the Same Lots of Fruit Cleaned at Harvest Time and After a Period of Cold Storage

Variety	Grains As_2O_3 per pound of fruit		
	Check	Cleaned at harvest time *	Cleaned February 1
Jonathan	.057	.029	.031
Delicious	.025	.0072	.0069
Winesap	.039	.0099	.014
Winesap	.051	.010	.011
Winesap	.035	.021	.023

* At harvest time the Jonathan and Delicious lots were cleaned with 0.3 per cent acid at 60° F. The first two Winesap lots were cleaned with 0.46 per cent acid at 76° F. and the last lot with 0.23 per cent acid at 90° F. On Feb. 1 all of the lots were subjected to 0.44 per cent acid at 84° F.

The operating conditions are given in Table 19. On the average the results do not indicate that the treatments were much more effective at 99° than at 76° F. With the Spitzenberg variety the highest acid temperature combination resulted in a reduction to .0052 grains per pound. The Winesap variety carried a heavy load of .051 grains per pound and the highest acid temperature combination left an arsenical load of .014 grains of As_2O_3 per pound of fruit.

These results with White's washer are too meager for any general conclusions. They tend to show, as does practically all of the above data on cleaning, that when the initial load is over .03 to .04 grains per pound it is much more difficult to effect removal over a low range,

such as from .013 to .005 grains than to remove a much larger initial amount of arsenical residue from the same fruit. This makes it appear that the spray residues become incorporated with or covered by the wax-like coating that forms on apples. In the case of some varieties, such as the Winesap, it is known that it is much more difficult to remove the arsenical residues after the fruit becomes waxy.

Table 19. Cleaning Effect of the White Washer upon Two Varieties of Apples Held in Cold Storage from Harvest Time until March 7

Variety	Per cent acid by weight	Temperature of acid	Time of treatment in sec.	Grains As_2O_3 per pound of fruit
Spitzenberg	——	——	Check	.033
Spitzenberg	.45	76° F	45	.011
Spitzenberg	.67	76° F	45	.011
Spitzenberg	.39	99° F	45	.011
Spitzenberg	.71	99° F	45	.0052
Winesap	——	——	Check	.051
Winesap	.45	76° F	45	.014
Winesap	.67	76° F	45	.0089
Winesap	.71	99° F	45	.014
Winesap	.39	99° F	45	.011
Winesap	.39	99° F	90	.0079

Size of Apples as Related to Effectiveness of Cleaning

Early in the course of the experiments in 1926 it was noted that small apples generally carried larger loads of As_2O_3 per pound of fruit than larger apples from the same lot (12).

Accordingly the fruit used for the experiments in 1927 was of as uniform a size as it was possible to obtain. An average size for a variety was selected whenever possible since an average size should represent the average load of As_2O_3. The sizes used for the different varieties ranged from 113 to 150 apples per box.

In some cases there was a variation in the size of fruit between duplicate samples. Some of these are listed in Table 20 for the purpose of making a comparison of the arsenical loads carried on large and small fruits. Only those sets of duplicates are included in

Table 20 which carried not more than .03 grains of As_2O_3 per pound for the reason that the natural variation between samples with larger residue loads becomes so great that the effect of size takes second place. Of those samples carrying less than .03 grains per pound in only two of the 12 pairs did the larger apples carry more arsenical residue than the smaller apples. The column of averages show that 30.8 per cent more As_2O_3 was found per pound of small than of large apples. The large apples of this lot were only 17.6 per cent larger than the small.

Table 20. Showing that the Smaller Apples Carry Larger Amounts of As_2O_3 per Pound of Fruit than the Larger Apples of the Same Lots

	Gram weights of duplicate samples of 6 apples each		Grains As_2O_3 per lb.	
	Sample 1 larger apples	Sample 2 smaller apples	Sample 1	Sample 2
Grimes Golden	835	789	.0067	.0084
Jonathans	721	686	.022	.028
Jonathans	682	600	.0061	.018
Delicious	1267	1019	.024	.019[1]
Delicious	1344	1133	.013	.013
Delicious	1265	1089	.013	.018
Arkansas Black	1077	978	.0085	.0090[1]
Winesap	807	641	.011	.022
Winesap	816	552	.018	.020
Winesap	806	675	.016	.021
Winesap	709	668	.012	.015
Winesap	780	719	.0089	.012
Average weight per apple	154.1	132.6		
Average grains As_2O_3 per lb.			.013	.017
Per cent greater load of As_2O_3				30.8

(1) Cases in which the larger apples carried the larger load of As_2O_3 per pound of fruit.

A greater difference in size, for instance in the case of apples that pack 200 as compared to 100 per box would have revealed a much greater effect of size. Mathematically, bodies have more surface per unit of weight in small than in large spheres. Since the amount of spray residue is undoubtedly related to the amount of

surface exposed, the principle of smaller spheres probably caused some of the above discussed relation between large and small apples. At the same time small apples have more stem and calyx ends per unit weight of fruit where, as previously shown, (12), about one-third of the arsenical residue of the apple is carried.

The Use of Special Sprays Previous to Harvest

At the time of the harvest of 1926 considerable attention was given to the use of special sprays, just before picking, in an attempt to remove sufficient amounts of the arsenical spray residues. The negative results and difficulties of this method are given in a previous bulletin (12).

This question of pre-harvest spraying with a special spray to effect a removal of the arsenical residue was strongly advocated by commercial interests during the 1927 harvest season. It was claimed with analytical data to support the claim, that the use of an "apple soap" spray removed some of the arsenical residue and caused the remainder to be so easily removed that dry brushing or wiping, rather than chemical wet cleaning, would be the only operation necessary.

Table 21. Cleaning Results Obtained when an Apple Soap Spray with Lye was Applied 6 Days Before Harvest

Cleaning process	Grains As_2O_3 per lb. of fruit	
	Sprayed with apple soap	Not sprayed with apple soap
None	.033	.038
Flotation and dip	.0093	.0093
Jet spray	.0054	.0065
Rotating bristle brushes	.027	——
Rotating rag wiper	.019	.017

For the purpose of testing this "apple soap" some Jonathan trees were sprayed six days before harvesting with a mixture consisting of 3 pounds of "apple soap" and 1.6 ounces of lye per 100 gallons of water. This was prepared according to the given recommendations and was applied at the rate of 40 gallons per tree at 400 pounds presssure. The results show (Table 21) that this soap spray did not remove any of the residue and that it did not make the residue any easier to remove by either dry or wet-process machines.

Arsenic in Commercial Hydrochloric Acid and its Accumulation in the Cleaning Solution

As a part of the search for the cause of calyx burning discussed elsewhere in this bulletin an investigation was made of the amount of arsenic that would accumulate in the cleaning solutions of hydrochloric acid. The cleaning solution of a commercially operated fan-spray machine was sampled at intervals and a record kept of the number of loose boxes of apples that had been cleaned. Table 22 shows that the amount of arsenic gradually increased during a day's run and tended to reach a maximum of about .266 grains of As_2O_3 per pound of cleaning solution. An appreciable amount of the acid cleaning solution was carried over into the wash water in this machine and the arsenic thus removed by the escaping wash water probably accounts for the slowing down of the rate of accumulation of arsenic in the acid cleaning bath.

Table 22 also shows that the amount of arsenic present in the wash water at the end of a day's run was quite low due to the introduction of fresh water.

Analyses of the concentrated commercial hydrochloric acids used at Wenatchee during the 1927 season gave an average of 0.462 grains of As_2O_3 per pound of acid. This seems quite high but is negligible when the acid is diluted for use. It amounted to only .0031 grains per pound in the cleaning solution used in the experiment of Table 22.

These data point out the importance of changing the acid solution to keep down the arsenic concentration therein. During the latter part of the 1927 season the general practice was to renew the acid bath once a day. The accumulation of fungous spores was also thus prevented as discussed in another part of this bulletin.

Table 22. Amount of Arsenic as As_2O_3 in Commercial Hydrochloric Acid Used at Wenatchee and in Acid Bath and Wash Water of a Fan Spray Process Machine at Stated Intervals

Number of boxes of fruit washed	Type of solution	Grains As_2O_3 per pound of solution				
		Dec. 5	Dec. 6	Dec. 7	Dec. 8	Average
225	.66% acid	——	——	.140	.161	.150
450	.66% acid	——	——	.178	.189	.184
625	.66% acid	——	——	.256	.224	.240
900	.66% acid	.294	.294	.231	.245	.266
900	Wash water	——	.014	.021	.014	.016
	Conc. commercial HCl acid; average of four lots used at Wenatchee					.462
	In unused .66% acid					.0031

The possibility of an excessive accumulation of arsenic in a washing solution is readily apparent when a computation is made of how much arsenic is removed from the fruit. A day's run of 1000 boxes represents about 40,000 pounds of fruit. A removal of .03 grains of arsenic calculated as As_2O_3 per pound gives a total of 1200 grains. In 200 gallons of cleaning solution 1200 grains gives an accumulation of .718 grains of As_2O_3 per pound of solution. This is much higher than the highest concentration found in the commercially operating fan-spray machine (Table 22). As stated above there was a constant transfer, in this machine, of acid and arsenic into the wash water bath from which the arsenic was removed by a constant over flow due to the incoming fresh water.

Arsenic in Normal and Burned Calyx Ends of Washed Apples

The search for the cause of calyx burning of apples involved a determination of the amount of arsenic in normal and burned calyx ends. Normal and calyx-burned apples were selected from the storage lots of Jonathans, the calyx ends of which were found to carry the amounts of arsenic recorded in Table 23. It may be seen that fruit cleaned either by an alkali or an acid process, carried approximately the same amounts of total arsenic in the normal as in the burned calyx ends.

Table 23. Total and Water Soluble Arsenic Found in Normal and Burned Calyx Ends of Washed Apples

Variety	Cleaning treatment	Condition of calyx	No. of calyx ends used	Mgs. As_2O_3 per calyx end	
				Total	Water soluble
Jonathan	Alkali without oil coating	Burned	21	.0022	
Jonathan	Alkali without oil coating	Normal	30	.0029	
Jonathan	Alkali with oil coating	Burned	11	.0038	
Jonathan	Alkali with oil coating	Normal	11	.0042	
Jonathan	Acid jet	Burned	19	.0034	
Jonathan	Acid jet	Normal	19	.0037	
Rome	Water only	Burned	10	.0017	.0012
Rome	Water only	Normal	10	.0013	.0011

Since calyx burning is considered to be due to arsenic in the soluble form as shown by Fisher and Reeves (7) an attempt was made to determine the soluble arsenic compounds in the calyx ends of Rome apples. It was found (Table 23) that a water extract yielded about the same amount of arsenic from the normal as from the burned calyx ends. Since nearly half of the total arsenic was thus extracted as soluble arsenic it was suspected that the malic acid of the apple tissue of the calyx ends was effecting a solution of the lead arsenate. This supposition was confirmed by shaking a quantity of lead arsenate with a solution of malic acid equivalent to the strength found in the juice of the apple. This procedure greatly

increased the soluble arsenic of the lead arsenate. There is the further possibility that the malic acid of the apple may cause considerable of the lead arsenate to become soluble in the event that it comes into contact with the juice of the fruit.

Cleaning Effect of Wet and Dry Process Machines Upon Pears

The wet process machines reduced the arsenical load below the world tolerance of .01 grains of As_2O_3 per pound (Table 24) on all of the samples of the three varieties of pears tested. It thus appears that any good acid-cleaning process, operating with low to medium strengths of acid and at normal temperatures, may be expected to remove a sufficient amount of the arsenical residue from Washington-grown pears.

Table 24. Cleaning Effects of Wet and Dry Process Machines upon Three Varieties of Pears

Cleaning processes	Grains As_2O_3 per pound of fruit		
	Bartlett	D'Anjou	Winter Nellis
Check	.035	.027	.021
Pressure jet	——	.0054	.0058
Fan spray	.0042	.0090	.0094
Flotation and spray	.0037	.0068	.0053
Flotation and dip	.0055	——	——
Box dip	.0062	.011	——
Vibrating bristle brushes	.0021	——	.0064
Rotary bristle brushes	——	.020	.012
Rag roller	——	——	.011

Dry cleaning did not prove to be sufficiently effective upon either the Bartlett, D'Anjou or Winter Nellis varieties of pears. The vibrating bristle brush machine reduced the arsenical load sufficiently on the Winter Nellis variety but caused the surface of the fruit to be scratched and marred to an objectionable degree. This scratching of the surface by dry process machines was also noticeable on the other two varieties, particularly the Bartlett.

THE RELATION OF CLEANING METHODS TO THE STORAGE BEHAVIOR OF APPLES

The widespread adoption of dry-cleaning methods in handling the apple crop of 1926 in the Pacific Northwest put upon the market a pack of improved appearance over that of previous years when wiping was an uncommon practice. The fruit cleaned by various dry wipers also stood up well in storage with but little increase in the percentage of decay (12). With the failure of dry wiping to satisfactorily solve the spray residue problem, and the consequent necessity for the extensive adoption of chemical processes of removal, growers were naturally apprehensive of the outcome, since wet cleaning was such a radical departure from all previous practices. The principal misgivings were with reference to two features: first, the danger of chemical burning either on the cheek or more especially at the calyx end, since before the adoption of wet-cleaning methods this latter type of injury was known to be favored by moisture; and second, the possible increase in the incidence of decay, especially blue mold. There was also an uncertainty as to the effect of the chemical methods on scald, internal breakdown, or loss of weight during the storage period.

Calyx Injury

The early exepriences with the wet-process machines show that calyx burning or "acid burning" as it was at first designated was one of the objectional consequences with certain machines, and especially with some susceptible varieties of apples. This occurrence af calyx burning (Figure 14) is well illustrated in Tables 25, 26, and 27, in which four varieties are compared with treatments by seven different wet-process machines and five dry wipers. The analysis of this table shows: (1) that calyx burning is greatly increased by the wet treatments as compared with dry wiping; (2) that it is not absent entirely from the checks and the dry-wiped lots; (3) that the Jonathan apples suffered much more injury than any of the other varieties (Table 25); (4) that the acid-process machines with a driving or jet spray caused the most burning; (5) that submerging processes

Table 25. Comparison of Calyx Injury and Rots in Four Varieties Cleaned by Various Wet and Dry Machines

Machine	Variety	No. of apples	No. of calyx burns		No. of calyx rots	No. of other rots	Total % decay for four varieties
			Slight	Pronounced			
Check	Jonathan	764	3	5	1	1	
	Delicious	281	1	0	0	3	
	Rome	673	0	0	1	6	
	Winesap	660	0	0	0	0	0.50
Jet spray	Jonathan	689	148	44	11	45	
	Delicious	278	0	0	0	1	
	Rome	705	0	30	0	14	
	Winesap	699	1	0	0	5	3.19
Fan spray	Jonathan	839	43	3	0	15	
	Delicious	281	3	0	0	2	
	Rome	693	0	0	0	2	
	Winesap	648	0	3	0	4	0.93
Flotation and spray	Jonathan	839	33	3	0	10	
	Delicious	313	0	0	0	5	
	Rome	306	0	0	0	4	
	Winesap	326	0	0	0	2	1.17
Flood wash	Jonathan	652	23	2	0	13	
	Delicious	221	2	0	0	5	
	Rome	323	2	0	0	2	
	Winesap	226	1	0	0	4	1.47
Flotation and dip	Jonathan	764	65	13	2	14	
	Delicious	278	4	0	0	2	
	Rome	325	3	0	1	3	
	Winesap	350	0	0	0	5	1.57
Box dip	Jonathan	614	88	33	2	10	
	Delicious	318	2	0	0	2	
	Rome	635	13	1	0	5	
	Winesap	679	3	0	1	4	1.06
Flotation and spray (alkali)	Jonathan	690	129	49	0	3	
	Delicious	280	21	2	0	4	
	Rome	614	68	14	0	6	
	Winesap	632	127	7	0	2	0.67
Vibrating brushes	Jonathan	715	15	1	0	1	
	Delicious	213	2	0	0	1	
	Rome	613	0	0	0	11	
	Winesap	738	1	0	0	9	0.96
Rotating bristle brushes	Jonathan	840	7	0	0	1	
	Delicious	206	0	0	0	1	
	Rome	346	6	0	0	0	
	Winesap	338	0	0	1	0	0.17
Rotating hemp brushes	Jonathan	740	3	0	0	7	
	Delicious	72	0	0	0	0	
	Rome	317	0	0	0	1	
	Winesap	313	0	0	1	2	0.76
Rag wiper	Jonathan	—	—	—	—	—	
	Delicious	213	0	0	0	0	
	Rome	305	0	0	0	4	
	Winesap	317	3	1	0	2	0.67
Rotating horsehair brushes	Rome	315	2	1	1	2	
	Winesap	315	0	0	0	4	0.99
Total	Total	23746	822	212	22	249	

(flotation and dip and box dip) also were an element of danger; and (6) that the alkali process (Brogdex) caused nearly as much burning as the most injurious acid process (Table 27.). Slight calyx burning as reported in Table 25 would probably be ignored in inspection, as in the cases so recorded only a few isolated burned specks or spots were evident in the calyx cavity, In pronounced calyx burn the necrotic area was more extensive and frequently involved the entire calyx cavity (See Figure 14).

Fig. 14. Severe type of arsenical calyx injury on Winesap apples.

Reference to the tabulation of results (Table 26) will show that of the four varieties compared, the Jonathan was much more susceptible to calyx burning. On the basis of the low number of pronounced burns and the very few calyx rots in such varieties as Delicious, Romes and Winesaps, this type of injury can not be considered very serious for the more resistant varieties. It is of interest in this connection to note the comparison of the amount of calyx burn resulting from the various wet processes. The tabulation of the results obtained with the Jonathan is selected as best representing the liability of the processes to cause calyx burning (Table 27). It appears that the driving or jet spray is a greater element of danger, than the other types of acid cleaning. Using the jet-spray

Table 26. Showing Total Calyx Burning and Total Rots of Four Varieties, Untreated and over All Machines. (Listed in Table 25)

Variety	Treatment	Total apples	Total no. calyx burns	% of calyx burns	Total No. rots rots	% of rots
Delicious	Untreated	764	8	1.04	2	0.26
Jonathan	Untreated	281	1	0.35	3	1.06
Rome	Untreated	673	0	0.0	7	1.04
Winesap	Untreated	660	0	0.0	4	0.61
Total	Untreated	2378	9	0.37	16	.067
Jonathan	Cleaned	7733	707	9.14	136	1.75
Delicious	Cleaned	2696	37	1.37	26	0.89
Rome	Cleaned	6152	136	2.21	63	1.03
Winesap	Cleaned	6431	154	2.39	46	0.71
Total	Cleaned	24012	1034	4.3	268	1.13

machine several different runs of Jonathans were compared using the machine with its normal driving jets and the same jets turned up against the cover so that the acid fell back upon the fruit. This treatment reduced the percentage of calyx burns to a very low number as compared to the number with the driving spray. Also the submerging (box dip and flotation and dip) causes more burning than simple flooding or fan spraying. The danger of the jet spray and submersion processes is further emphasized by the percentage of calyx burns which served as infection courts for blue mold. Here also the jet-spray process led to the highest percentage of decay. It is of interest to note here that although the alkali process caused

Table 27. Comparison of the Amount of Calyx Burning in Jonathans Treated by the Different Wet Process Machines

Treatment	No. of apples	No. of calyx burns	Percentage of apples showing calyx burns	% of calyx burns developing rot
Jet spray	689	192	27.86	5.72
Fan spray	839	46	5.48	0.0
Flotation and spray	839	36	4.29	0.0
Flood wash	652	25	3.83	0.0
Flotation and dip	764	78	10.21	2.56
Box dip	614	121	19.71	1.56
Flotation and spray (alkali)	690	178	25.79	0.0

nearly as much calyx burning as the acid jet spray, that none of the alkali calyx burns served as infection courts for blue mold (Table 27).

The relation of wet packing to the percentage of calyx burns was tested with a number of varieties held in common storage and in cold storage, the latter with three different percentages of humidity: ordinary, dry and humid (Table 28). In the case of the Rome, calyx burn seemed to be increased by wet packing; but this was not the case with the Winesap. The results were variable for Jonathans so that definite conclusions as to the effect of wet packing on calyx burn are not justified from these tests.

Table 28. The Percentage of Calyx Burn in Several Varieties Packed Wet and Dry and Stored under Different Temperatures and Humidity. (Data based on 8 boxes over the wet process machines 727-1003 apples; and 4 dry wiped boxes)

Variety	Storage	Wet cleaned		Dry wiped
		Wet pack	Wet pack	
Rome	Ordinary cold storage	2.11	0.79	0.0
	Humid cold storage	0.	——	——
	Dry cold storage	0.65	——	——
	Common storage	7.83	3.39	1.47
Winesaps	Ordinary cold storage	0.0	0.12	0.51
	Humid cold storage	0.27	——	——
	Dry cold storage	0.29	——	——
	Common storage	0.0	0.26	0.0
Jonathan	Ordinary cold storage	3.58	1.15	0.92
	Humid cold storage	7.24	9.74	4.75
	Dry cold storage	3.22	2.44	1.52

The types of storage were also compared as to the relation to calyx burning. The dry pack (Table 28) which represents the commercial practice of the season shows more calyx burn in common than in ordinary cold storage. Three percentages of humidity were available in cold storage, ordinary, humid, and dry. See p. 79 for differences in humidity. Of the lots represented in Table 28, four of the five showed the most burning in humid cold storage, while

an average of five lots gave slightly more burning in the dry cold storage than in the ordinary or common cold storage. From these results there is no reason to conclude that the humidity of the cold storage is a very important factor in relation to calyx burn. The indications are however than an excessive humidity of the storage room is more conducive to burning than ordinary humidity or an especially dried air.

At the beginning of the present packing season calyx burning was referred to as acid burning and was attributed to the accumulation of hydrochloric acid in the rinse bath. Our observations and tests and those of Fisher and Reeves (7) have led to the conclusion that the so-called acid burn is arsenical burning due to the free arsenic in part liberated by the action of the hydrochloric acid on the lead arsenate but only in small part to free arsenic that is present in ordinary commercial hydrochloric acid used for the cleaning bath (Table 22). The conclusion was presented in the more detailed studies reported by Fisher and Reeves (7). The main evidences for this conclusion are: (1) Calyx burn has been noted on fruit while still hanging on the tree; (2) it has been noted in previous years to result from allowing fruit to remain unprotected in the packing boxes in the orchard during soaking rains; (3) it has been increased by drenching fruit with water and packing wet in experimental lots not subjected to the acid cleaning process; (4) the same type of calyx burn has been observed in apples cleaned by dry wiping (Table 25, although much less in amount than in wet-processed fruit; (5) typical calyx burn has followed the use of perfectly pure rinse water free from all traces of acid; (6) there is no constant relation between the degree of acidity of the rinse water and the amount of burning, low acidity cometimes showing more burning than higher acidity (Tables 29 and 30); (7) the use of soda in the rinse bath has reduced calyx burn to some extent.

Apples of three varieties were packed without subjecting them to the ordinary rinse of pure water following the acid treatment, and one box packed wet, another after drying, and held in both common and cold storage. The results as presented in Table 31 showed that injury was very pronounced in all of the dry packs, in

Table 29. Effect of Acid in the Rinse on the Percentage of Calyx Burns in Jonathans Treated with Jet Spray (.33 acid). Treated Oct. 4—Examined Nov. 23... Common storage

Acid in rinse	Pressure	Percentage calyx burns	
		Packed dry	Packed wet
Check	———	0.0	——
None	With	15.2	19.7
None+soda	With	4.2	——
None+soda	Without	0.0	——
.02	With	18.5	17.8
.04	With	30.4	19.5
.06	With	35.1	20.1
.125	With	49.6	45.0
.19	With	56.3	53.0
.19	Without	8.8	——

Table 30. The Percentage of Calyx Burns in Several Varieties Packed Wet and Dry Following the Use of an Acidifier Rinse

Acid strength in rinse % by weight	Machine	Jonathans		Yellow Newton		Winesaps	
		Packed dry	Packed wet	Packed dry	Packed wet	Packed dry	Packed wet
.04 or .05 HCL	Jet spray	5.88	2.94	14.93	8.74	2.35	0.0
	Fan spray	0.0	0.0	18.28	2.91	1.0	0.0
	Box dip	0.0	1.47	16.00	8.16	0.0	2.0
.20 HCL	Jet spray	33.71	20.00	14.28	3.66	3.92	3.88
.20 HCL	Fan spray	0.0	5.77	3.45	21.11	6.41	12.67
.10 HCL	Box dip	6.06	0.0	0.0	3.84	3.12	3.70

some lots all fruits showing acid burning on the side as well as the common calyx burning. The injury was especially severe in the Yellow Newtown. The percentage of fruits showing burning in the wet packs was in general less than in the dry-packed fruit, the side burning showing a much more pronounced reduction than the calyx burning. In these tests the dry-packed stock was allowed to air dry in the packing shed for two days. The practical application of these results lead to the conclusion that if fruit is not carefully rinsed to remove the acid and then allowed to air dry, that there is greater danger of burning than if the fruit is packed while still wet. The evident explanation for this behavior of fruit must be

attributed to the absorption of the acid and soluble arsenic by the paper wraps and possibly to the retarded evaporation. If fruit is not washed to remove the acid or the acid as only partially removed and is then allowed to air dry before packing, acid burning is likely to result. A plausible explanation for this is that rapid drying concentrates the hydrochloric acid remaining, while with slow drying the acid also evaporates and does not reach an injurious concentration. This conclusion is substiantiated by the fact that there was only a moderate reduction of calyx burning in the wet packed lots, which would be explained by the fact that only a part of the moisture in the calyx cup or the basin would be absorbed by the paper. The results cited in Table 31 were confirmed by similar results reported by Mr. Harry Jensen, Assistant Horticulturist at the Irrigation Branch Station at Prosser for Jonathan, Rome, Delicious, Yellow Newtown and Winesap.

Table 31. Percentage of Arsenical Burning in Apples Treated with Acid (.33) and Not Rinsed

Variety	Storage	Packed dry		Packed wet	
		Calyx burn	Side burn	Calyx burn	Side burn
Jonathan	Common	11.1	100.0	9.8	0.0
Winesap	Common	0.0	93.3	4.0	4.0
Winesap	Cold	8.2	72.7	2.7	0.0
Yellow Newton	Common	34.5	100.0	21.4	1.4
Yellow Newton	Cold	3.3	100.0	2.5	1.2

Core Injury

In the case of apples which have an open calyx canal leading directly into the core cells there is an added element of danger from arsenical injury or acid penetration. A burning or discoloration of the walls of the core cavity may result, this in the nature of brown corroded streaks or broader patches of dead brown tissue. This discoloration in itself would be of little consequence if it were not for the relation it may bear to the incidence of moldy core or core rot. It is a well known fact that some varieties of apples may have a certain percentage of open calyx canals and that this peculiarity

will vary in a given variety, being influenced by the conditions under which the apples have been grown. The principal varieties used in our cleaning and storage tests were examined for the percentage of open calyx canals with the following results:

Jonathan	20.52
Delicious	16.83
Rome	0.
Winesap	4.11
Yellow Newtown	16.33

The relation of the different types of cleaning to core injury in Jonathans is shown in Table 32. It may be noted that this core injury is slight in most of the processes, but that it is apparently increased by treatments in which the fruit is submersed as in the flotation and dip, and box dip lots, in which 80 and 69.38 per cent respectively of the open cores were injured. The greater injury in

Table 32. Relation of Calyx Canals to Core Injury in Jonathans Treated by Different Machines. Treated Sept. 28—Examined Feb. 9-24

Type of treatment	Total no. apples examined	Open calyx canal			Closed calyx canal		
		Without mold or discoloration	With discoloration or burning in core	Total	Without discoloration	With discolored core walls	Total*
Check, no treatment	288	48	7	56	225	7	232
Jet spray	278	37	0	66	68	0	68
Fan spray	275	35	0	48	227	0	227
Flotation & spray	251	53	0	56	195	0	195
Flood wash	275	45	5	58	209	8	217
Flotation & dip	275	13	25	65	203	7	210
Box dip	326	15	21	49	273	4	277
Flotation & spray (alkali)	301	38	12	56	241	4	245
Vibrating brush	301	54	1	59	242	1	243
Total	2570			513			1913

* This total includes open canals that led to moldy core or core rot (see Table 49).

Percentage of calyx canals open—20.

the flotation and dip process may possibbly be explained by the longer period in the acid vat (5 to 6 minutes) and the successive submerging (see p. 23). The discoloration of the core walls in some fruits with closed calyx canals was slight and apparently in the nature of beginning breakdown.

Types of Apple Rots in the Northwest

There are three important defects in apples which develop in storage: **scald**, the common type and the so-called soft scald; **physiological breakdown**, or senility necrosis, generally referred to as internal breakdown; and **rot** or decay due to the inroads of rot-producing fungi some of which can gain an entrance into sound fruits only through mechanical injuries or necrotic spots, while others are capable of penetrating the unbroken epidermis.

In the Pacific Northwest these storage rots which are due to numerous species of fungi may be placed in the four following groups:

1. **Blue molds**, represented by several distinct species, of which one known as **Penicillium expansum** is outstanding because of its very general occurrence and fairly rapid growth even at cold storage temperatures. The common blue mold produces a light brown, soft rot upon which the bluish green, fruiting or sporulating tufts of the fungus appear.

2. The **gray molds** including several species of unrelated fungi which show one character in common, namely, a grayish or whiteish growth whenever the fungi come to the surface of the rotted areas. Some of the more important of these are the common grey mold or **Botrytis** rot with its special type, the so-called spot rot, and several species of **Fusarium, Pestalozzia** and **Rhizopus**, the latter sometimes referred to as black mold. The decayed areas are generally slightly darker and somewhat firmer than in blue-mold rot.

3. The **black rots**, characterized by the dark brown or black coloration of the decayed tissue, which is generally much firmer than in either the blue molds or the gray mold. Most of these are slow-growing at cold storage temperatures in comparison with blue mold.

In the Northwest these rots are generally referred to by the Inspection Service as **Alternaria rots,** but they are in reality due to numerous species of several genera of fungi of which Alternaria is but one. Some of the more important genera, a number of which contain several distinct types or species which can only be recognized by careful microscopic study are **Alternaria, Stemphylium, Pleospora, Cladosporium**, and **Phomopsis.** In most of the rot-producing fungi included in this group the vegetative body of the fungus which appears on the surface of the rotted areas is brown or dark olive in color.

4. The **anthracnoses,** represented by the fruit-rotting phases of the black-spot or Pacific-Coast canker, and the perennial canker, the latter under the name of false anthracnose or bull's-eye rot.

In the main commercial apple districts of Washington the gray molds, black rots, and anthracnoses, sink into insignificance when compared to blue mold as a cause of storage or transit losses. Perennial canker is known to occur in all parts of the state east of the Cascades, but it is of minor importance except in several localized sections, while blue mold is a problem in every packing house and storage plant. In regions in which the perennial canker rot is prevalent it is more serious than blue mold since it is able to penetrate the unbroken epidermis.

Blue Mold During the Crop Seasons of 1925, 1926, and 1927

Since the chemical cleaning of fruit has been practiced during the past packing season on a rather large scale without the results of previous commercial experience, it might be the tendency to attribute heavy blue mold losses to the new methods of handling. In order that we may have the proper perspective, it may be well to inquire as to the blue mold situation during the past few seasons when methods of handling apples have been undergoing change. Previous to the crop of 1926, apples were packed with but little attention to cleaning, and carried into storage most of the dirt and spray residue that had accumulated during the growing season. The crop of 1926 was very generally dry cleaned either by hand or by machines, while a high percentage of the crop of 1927 has been

cleaned by one of the chemical or wet processes. The crops of 1925, 1926, and 1927 will then represent three diverse methods of handling.

The results of car lot inspections of apples at Eastern markets may be taken as a fair index of the blue mold situation in these years. Results of these inspections have been compiled from the records of the Federal Inspection Service (Table 33-37).

Table 33. Results of Car Inspections at Eastern Markets. Crop of 1925. No Wiping

Month of inspection	No. of cars showing blue mold	Average % blue mold	Highest av. % blue mold car lots	Highest % blue mold box lots	No. cars without decay
Aug. 1925	—	—	—	—	7
Sept. 1925	11	2.36	10	50	100
Oct. 1925	10	1.30	3	3	275
Nov. 1925	61	4.09	25	50	230
Dec. 1925	90	3.67	55	65	230
Jan. 1926	65	2.90	10	35	86
Feb. 1926	106	3.55	30	50	100
Mar. 1926	136	4.07	20	75	102
April 1926	189	3.35	50	60	110
May 1926	69	3.91	20	60	50
June 1926	51	4.76	25	35	13
July 1926	7	7.28	20	20	4
	795	3.76	24.36	45.72	1307

For the crop of 1925 in which little or no wiping was practiced 37.8 per cent of the cars inspected showed blue mold ranging from .05 per cent to a maximum of 55 per cent or an average for the 795 cars of 3.76 per cent. For 1926 when dry cleaning was practiced 40.8 per cent of the cars inspected showed blue mold ranging from .05 per cent to 55 per cent or an average for the 733 cars of 3.65 per cent. The highest percentage of blue mold in any boxes is also quite comparable for the two seasons. These figures show that blue mold took a fairly heavy toll during 1925 and 1926 before chemical removal of spray residue was in operation. On the basis then of previous experience considerable loss from blue mold may be expected unless the new methods of handling prove to be superior to the old methods.

It is too soon to have completely comparable data for the 1927 crop, but on the basis of the Eastern inspection reports that have been received, the outlook is very promising. While the percentage of cars inspected from September to January inclusive that show blue mold decay has been somewhat higher for the 1927 crop than for either 1925 or 1926, (Table 36), the average percentage of blue mold in the cars showing decay has been less than in the two previous years except for the months of September and October when it was higher (Table 37). The higher percentage of blue mold at the beginning of the season is probably explained by the use of

Table 34. Results of Car Inspections at Eastern Markets. Crop of 1926. Dry Wiped

Month of inspection	No. of cars showing blue mold	Average % blue mold	Highest average % blue mold	Highest % of blue mold	No. cars without decay
Aug. 1926	—	—	—	—	38
Sept. 1026	4	1.5	2	8	104
Oct. 1926	45	2.7	10	80	240
Nov. 1926	55	2.56	8	30	205
Dec. 1926	79	5.46	55	90	125
Jan. 1927	127	3.9	30	65	111
Feb. 1927	118	2.87	13	50	98
Mar. 1027	115	3.9	28	60	85
April 1927	70	4.08	20	50	27
May 1027	58	3.46	16	30	26
June 1927	51	6.7	25	45	3
July 1927	11	3.1	15	60	—
	733	3.65	20.18	51.63	1062

Table 35. Results of Car Inspections at Eastern Markets for Crop of 1927. Both Wet and Dry Cleaning

Month of inspection	No. of cars showing blue mold	Average % blue mold	Highest Av. % blue mold car lots	Highest % blue mold box lots	No. cars without decay
Sept. 1927	8	4.47	14	25	53
Oct. 1927	71	4.65	50	80	134
Nov. 1927	94	2.75	45	70	225
Dec. 1927	102	3.01	16	40	156
Jan. 1928	146	2.44	25	40	152

Table 36. Showing the Number of Car Lots of Apples Inspected at Eastern Markets with the Percentage of Such Cars Showing Blue Mold

Month	1925 Crop—no wiping		1926 Crop—Dry cleaning		1927 Crop—Wet and dry cleaning	
	No. of cars	% of cars showing blue mold	No. of cars inspected	% of cars showing blue mold	No. of cars inspected	% of cars showing blue bold
Sept.	111	9.9	108	3.7	67	11.9
Oct.	285	3.5	285	15.78	205	34.63
Nov.	291	20.96	266	20.7	353	26.62
Dec.	320	28.12	204	38.72	258	36.23
Jan.	151	29.8	238	53.36	298	48.99
Jan.	151	29.8	238	53.36	298	48.99

washing methods that were later avoided because of believed danger in promoting the incidence of rots. The inspection records cited and commercial practices in the producing districts of the state certainly indicate that wet cleaning for the removal of spray residue is not going to cause any material increase in the majority of storage decays, and may result in an improvement when the methods have finally become standardized.

Table 37. The Average Percentage of Blue Mold in Cars Showing Decay

Month of inspection	1925 crop	1926 crop	1927 crop
Sept.	2.36	1.50	4.47
Oct.	1.30	2.70	4.65
Nov.	4.09	2.56	2.75
Dec.	3.67	5.46	3.01
Jan.	2.90	3.90	2.44

The Fungous Flora of Normal Apples

In considering the relation of cleaning methods to blue mold it should be of interest to note that there are many fungous spores on the surface of normal apples. A great many different analyses have been made in our Experiment Station Laboratory by Mr. Huber, Fellow in Plant Pathology. As a result of these tests it may be stated with certainty that perfectly normal sound apples removed from packed boxes are carrying upon their surface from 5000 to as many as 100,000 viable or live spores of fungi; and further that these numbers show little or no decrease during the storage life of fruit and in some cases an increase in numbers. Some of the fungi present are perfectly harmless forms, while others are rot-producing species ready to start decay if they are offered any avenues of entrance. (Figure 15).

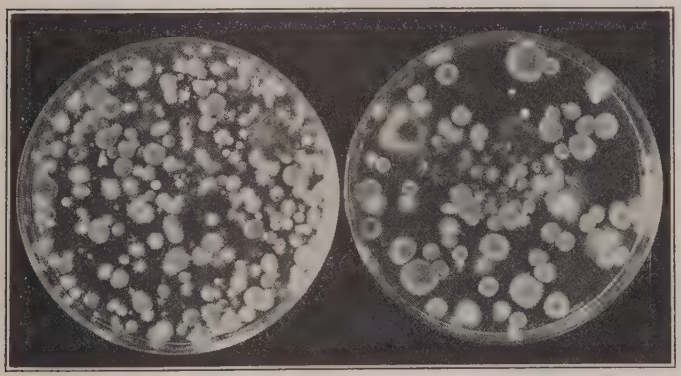

Fig. 15. Photos of culture plates made from the wash water in which normal sound apples were scrubbed. Left, 1/100 cubic centimeter. Right, 1/200 cc. The colonies shown are mostly Cladosporium, Penicillium, Alternaria and Dematium types.

Among the rot-producing forms prevalent upon normal apples are blue molds, in fact some one of these is almost always present. The number of blue mold or other fungous spores present will vary with the age of the fruit and the conditions to which it has been

subjected before being packed. This very general prevalence of blue mold on the surface of normal apples may be indicated by certain tests. For example, Jonathans that were artificially stem punctured, wrapped in oil wraps and packed in boxes (Oct. 13) showed 43 per cent of the punctures infected with blue mold after five weeks in common storage, while similarly treated Winesaps which were held in cold storage until spring and then punctured and packed showed 100 per cent of the punctures infected.

The determination of the spore load of normal sound apples indicate that dry wiping as carried out for the crop of 1926 had but little effect in the removal of fungi. The conclusion seems to be justified that dry wiping does the same for fungous spores on the apple as it does for the spray residue, that is, they are spread by the cloths and brushes and rubbed into the wax, lenticels, russet areas, or cracks. These analytical results are corroborated by the fact that dry wiping has shown no consistent reduction in storage rots, while in some cases dry cleaning of fruit has even been followed by an increased percentage of decay.

The Accumulation of Spores of Fungi in the Cleaning Solutions

When apples are cleaned by the use of a chemical solvent large numbers of fungous spores have been found to accumulate in the chemical vat or tank and also in the water of the rinse bath. It is important to understand the origin of these spores. There are three common sources: first, from the surface of normal, sound apples passed through the machine; second, from the dust of the air; and third, from an occasional partially rotted apple that may be allowed to pass into the machine. Unfortunately the solvents used for the removal of arsenical residue have little if any immediate killing effect upon the spores with which they come in contact, consequently the number of viable spores or those capable of germinating that are left behind in the tank is on the increase during the period of operation and may reach a rather high number by the end of a single day's run. Also it should be borne in mind that the treated apples will carry many of these spores over into the rinse bath, which may

also become heavily charged, especially if a closed or repumped rinse is employed. A fresh rinse of water that is never repumped will carry away many of the spores that otherwise might remain on the surface of the fruit and thus pass into storage.

Numerous analyses have been made of the spore content of the cleaning solution from various types of machines at the end of the day's run with special emphasis on the number of blue mold spores. (Table 38). Our determinations have been made under normal or average packing house conditions and should represent a fair cross section of conditions which prevail in actual practice. These analyses have shown from 200 to a maximum of 12,300 spores of blue mold per cubic centimeter in the cleaning solution at the end of a day's run, and a much higher number of spores of other species, mostly of lesser importance (Cladosporium, Alternaria, Dematium, etc.) Very similar results will be found in the water of the rinse tank if a closed or repump system is used. In order to give emphasis to this accumulation of blue mold spores, the total number in a 100-gallon tank on the basis of these analyses may be noted. This has varied from 75,000,000 to over 4,500,000,000. The extent to which the spore content may be increased by allowing partially decayed apples to pass into the machine is illustrated by Nos. 8 and 9 (Table 38). This increase was the result of adding the product of about a dozen badly rotted apples to each acid tank.

It seems reasonable to believe that a very high percentage of the spores that accumulate in the cleaning tanks would have been carried on into the packing room and into the boxes of packed fruit if they had not been removed in the cleaning operations. Theoretically then, wet cleaning if properly carried out should offer less opportunities for the entrance of decay.

The importance of keeping down the blue mold spore content of the treating and rinse baths has been emphasized by commercial experience and by experimental tests. Some of the early disastrous results of wet cleaning when heavy losses were due to the blue mold decay, are to be explained by the employment of repumped rinse, combined with arsenical calyx burning. Some experimental tests

may also be cited. Jonathans in box lots were artificially stem punctured, cleaned with a jet machine and packed immediately. When they were cleaned with an acid solution carrying approximately 1000 blue mold spores per cubic centimeter, 23.1 per cent of the punctures became infected with the blue mold, but when they were obliged to run the gauntlet of 53,500 spores per cubic centimeter, the percentage of infection was increased to 79.7. Other tests have shown a similar relation of decay to the number of blue mold spores in the cleaning solution in the case of commercially sorted fruit, altho the percentage of infection is very low in comparison with artificially punctured lots.

Table 38. Number of Spores of Fungi in the Treating Bath Taken from Various Treating Machines

Number	Type of machines	Date 1927	No. blue mold per cc.	Total of all fungi per cc.
1	Flotation and dip	9–29		
	After standing 24 hrs.		266	1,370,000
	After standing 48 hrs.		283	1,030,000
2	Box dip,	9–29		
	After standing 48 hrs.		200	378,000
3	Jet spray	10–10	600	12,900
4	Fan spray	10–10	3,250	24,950
5	Flotation & spray (alkali)	10–11	378	720
6	Jet spray	10–11	12,300	18,850
7	Fan spray	10–12	366	6,500
8	Jet spray	10–14	53,400	Few others 4,200
9	Jet spray	10–14	58,500	81,600
10	Fan spray	10–21	1,000	27,600
11	Fan spray	10–21	900	47,000
12	Jet spray	10–21	1,000	19,000
13	Jet spray	10–24	250	?
14	Flotation and dip	10–24	600	34,000
15	Flotaton and spray .. (alkali)	10–26	342	1,000
16	Box dip ,	10–26	1,400	25.000

There are several different methods by which the spore content of the cleaning solutions and rinse bath may be kept down to a low figure. The following may be enumerated: (1) by preventing partially decayed apples from going through the machine; (2) by a prewash; (3) by frequent changes of the acid bath; (4) by a continuous spray

of fresh water as a rinse; (5) by sterilization of the treating bath and rinse over night; and (6) by the use of fungicide during the regular run. The value of these practices is based in part upon experimental evidence, and in part on the results obtained in commercial packing. The most of the trouble was experienced during the early weeks of the packing season, when many of these precautions were not observed, but as the season advanced and experience accumulated, greater care was observed. In the most carefully supervised packing houses at least the following precautions were observed: (1) An attempt was made to pick out partially decayed fruit on the receiving table; (2) the acid cleaning solution was changed at the end of each day's run; (3) machines that were built to use a closed or repump rinse were equipped with an additional supply of fresh water to complete or perfect the rinsing operation; and (4) the entire machine was sterilzed over night by the use of formaldehyde.

The Sterilization of the Acid Tanks.

Through the courtesy of the American Fruit Growers at Wenatchee an opportunity was afforded to test the effect of formaldehyde in reducing the blue mold content of the acid cleaning solutions under actual packing house conditions. Definite amounts of formaldehyde were added to the acid tank, the machine run for 15-20 minutes, then allowed to stand over night and run again for 15-20 minutes. Samples of the acid bath were taken before the test was started and again after the all-night treatment with formaldehyde and analyses made immediately for the blue mold content. The results are shown in the accompanying summary (Table 39). At the beginning of the season formaldehyde was used at the strength of one gallon of commercial product to 100 gallons of water. It may be noted that this strength is much more concentrated than is necessary to effect a complete sterilization, as a complete killing of blue mold and other fungous spores was accomplished with a strength of 1 gallon to 800 gallons of water.

Later the two strengths of formaldehyde which had shown a complete killing of the blue mold for the all-night period, were

Table 39. Tests on the Use of Formaldehyde in Sterilizing the Acid Wash of Apple-Cleaning Machines

(Temperature approximately 60° F.)

Machine	No. of blue mold spores per cc. at end of day's run	Blue mold spores after use of formaldehyde over night		
		Strength of F.	No. of blue mold per cc.	Percentage of blue mold alive
Jet spray	* 53,400	1–100	0	0.0
Jet spray	* 58,500	1–200	0	0.0
Jet spray	600	1–200	0	0.0
Fan spray	3,250	1–400	0	0.0
Fan spray	1,000	1–800	0	0.0
Fan spray	900	1–1200	38	4.2
Jet spray	1 000	1–1600	52	5.2

* This high number is due to the intentional introduction of blue mold from badly rotted fruit.

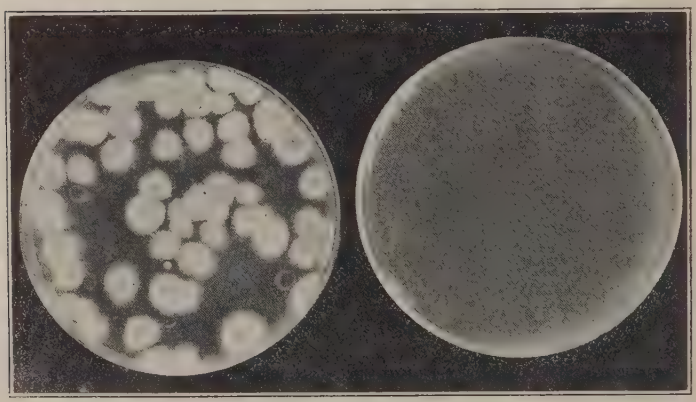

Fig. 16. Photos of cultures made from the acid vat of a Cutler Jet machine. Left, at the end of a day's run showing numerous colonies of blue mold and a small number of others. Plate represents 1/1200 cubic centimeter. Right, after sterilization over night with 1-400 formaldehyde.

tested for shorter lengths of time with the results shown in the accompanying tabulation (Table 40).

The tests here reported show that a washing machine may be completely freed of living blue mold spores by treatment with 1-800 of formaldehyde in the way indicated. It would further be evident from these figures that the use of a 1-400 solution of formaldehyde during the regular run would be more than equal in protection to changing the acid bath every five hours, while even the 1-800 strength would be of great value in keeping down the number of blue mold spores, since only one-fourth of the accumulated number would be alive at the end of the run.

Table 40. The Number of Spores of Blue Mold per Cubic Centimeter in the Acid Bath after Treatment with Formaldehyde
(No. of blue mold per cc. in the untreated acid bath—1025)

Duration of action	Form. 1-400		Form. 1-800	
	No. of blue mold spores per cc.	Percentage of blue mold spores alive	No. of blue mold spores per cc.	Percentage of blue mold spores alive
1 hr.	750	73.	947	92.4
2 hrs.	61	5.9	492	48.0
5 hrs.	0	0	262	25.4
12 hrs.	0	0	0	0.0

Opportunity has not been afforded to obtain adequate tests of the continuous use of these weak solutions of formaldehyde in regular commercial packing. It is certain however, that sound fruit may be treated with even stronger solutions of formaldehyde than 1-400 or 800 without injury to the fruit. Strong solutions of formalehyde may be a source of danger to the workers in closed packing rooms, but it is felt that these weaker solutions may be safely used without any danger to the workers. If this disinfection of the acid bath can be practiced it would obviate the necessity for the daily change of the acid. The bath would then require changing only when polluted with dirt and debris to such an extent as to interfere with

the mechanical action of the washer or because of the accumulation of soluble arsenic.

The Effect of Wet Packing on the Incidence of Rots

In cleaning apples by the wet processes the danger of imperfect drying before packing has been stressed, but it seems that this danger has been over emphasized. Fears had been expressed that even a little free moisture left in the calyx would cause increased incidence of rots, especially blue mold.

Table 41. The Percentage of Calyx Infections of Blue Mold in Jonathans from Packing Wet with Heavy Inoculum. (Packing House Storage)
Treated and Packed Oct. 13—Final Examination Nov. 22.

Treatment of fruit	Percentage showing calyx infections	
	Ordinary box pack	Held in saturated air
Water suspension of blue mold in calyx	0	15
Acid suspension (.35) of blue mold in calyx	14	67
Acid suspension (.35) of blue mold in calyx	10	—

The difficulty that blue mold finds in entering a normal sound calyx may be shown by some of our experimental packs. (Table 41). A rich mixture of blue mold from decayed apples was prepared in water and in hydrochloric acid of the average strength employed in the cleaning machines. The calyx bowls of box lots, (100 apples each), of Jonathans were then filled with these spore suspensions, the apples were wrapped carefully and packed calyx end up so as not to spill out any of the inoculum. These tests show that there was no infection when the water suspension was usd in the ordinary pack, but that infections did take place if storage was in a saturated at-

mosphere. When the acid suspension of blue mold was used there was considerable infection in the ordinary pack and a very high percentage when the storage was in a saturated atmosphere. Either the direct or indirect injury from the use of the acid was apparently responsible for the infections. It may therefore be concluded that moisture alone in the calyx, without some accompanying injury is of minor importance as affecting the development of blue mold decay.

In this connection it should be of interest to note the behavior of wet and dry packing of apples treated by the various machines. For these tests apples from the same lot were treated, and one box dried by the method adopted for that machine, while a sufficient number for a duplicate box were removed from the machine without going through the dryer, and wrapped and packed immediately. The figures given in Tables 42-45 for each variety represent five to seven different lots given various treatments in addition to the wet and dry check or untreated boxes. The several varieties were held both in common and regular cold storage. Under regular cold storage (Table 42) three of the dry-packed variety lots showed slightly more decay than the wet packs, while in one variety, the Winesap, the wet packs yielded slightly more rot. The differences are apparently no

Table 42. Showing Relation of Dry and Wet Packing of Apples to the Development of Decay in Ordinary Cold Storage

Variety and pack	Date treated	Dates examined	No. of lots	Total no. of apples	No. apples showing decay	Total % of decay
Jonathan						
Dry pack	Sept. 23-25	Jan. 7-30	6	1040	21	2.01
Wet pack	Sept. 23-25	Jan. 7-30	6	1064	14	1.31
Delicious						
Dry pack	Sept. 20-21	Feb. 2-14	8	803	3	0.37
Wet pack	Sept. 20-21	Feb. 2-14	8	858	2	0.23
Rome						
Dry pack	Oct. 11-18	Mar. 8	8	850	11	1.29
Wet pack	Oct. 11-18	Mar. 8	8	929	10	1.07
Winesap						
Dry pack	Oct. 24-31	Mar. 9	8	915	2	0.21
Wet pack	Oct. 24-31	Mar. 9	8	902	8	0.88

more than might be expected from sample variation. Under common storage (Table 43) four of the variety lots showed more rot in the wet packs than in the dry, while for one dry-packed variety lot more rot was recorded than for the wet pack. In four of the five variety lots the difference between wet and dry packs was very small. From the behavior of these lots the conclusion seems justified that packing the apples while wet had but little effect on the incidence of decay.

Table 43. Showing the Relation of Dry and Wet Packing of Apples to the Development of Decay in Common Storage

Variety and pack	Date treated	Date examined	No. of lots	Total no. of apples	No. apples showing decay	Total % of decay
Jonathan						
Dry pack	Oct. 26-27	Nov. 24-25	10	623	1	0.16
Wet pack	Oct. 26-27	Nov. 24-25	9	553	1	0.18
Yellow Newtown						
Dry pack	Oct. 26-27	Dec. 15 to	10	781	48	6.14
Wet pack	Oct. 26-27	Jan. 9	10	921	79	8.57
Winesap						
Dry pack	Oct. 26-27	Dec. 27 to	10	874	16	1.83
Wet pack	Oct. 26-27	Jan. 9	9	865	56	6.47
Dry pack	Oct. 24-31	March 1	7	891	23	2.58
Wet pack	Oct. 24-31	March 1	7	840	17	2.02
Rome						
Dry pack	Oct. 11-18	March 1	8	926	8	0.86
Wet pack	Oct. 11-18	March 1	8	802	19	2.35

It has been repeatedly demonstrated that fresh punctures are easily infected with blue mold, and the question naturally arises as to whether the presence or absence of mechanical injuries may affect the results with wet and dry packing. The tests recorded in Table 44 yield some information on this point. Punctured apples treated at the end of the day's run and packed both wet and dry gave two times as many mold infections in the wet pack as in the dry. Opportunity was also offered to note the effect of formaldehyde in the acid tank in reducing the number of infections from blue mold. Where

formaldehyde had been used the wet packs gave less rot than the dry packs, presumably as a result of the longer action of the formaldehyde in the wet-packed stock.

Whether wet packing would increase the incidence in decay in large scale commercial packing would appear to depend largely upon the presence or absence of mechanical injuries which would offer an avenue of entrance for the blue mold. (The behavior might be different with perennial canker rot which can infect the perfectly sound fruit).

Table 44. Showing the Effect of Formaldehyde in the Acid Tank on the Percentage of Punctures* Infected with Blue Mold

No. of blue mold spores per cc. in the acid tank	Strength of form. in acid tank	Length of action of form.	Per cent of blue mold decay after 5 weeks in common storage	
			Packed wet	Packed dry
600 spores of blue mold per cc.				
At end of day's run	None	None	54.6	23.1
53,500 spores of blue mold per cc.	None	None	96.	79.7
53,500 spores of blue mold per cc.	1–100	5 min.	34.3	54.7
53,500 spores of blue mold per cc.	1–100	25 min.	15.5	45.4
53,500 spores of blue mold per cc.	1–100	Overnight	6.	22.5
53,500 spores of blue mold per cc.	1–200	5 min.	67.	96.6
53,500 spores of blue mold per cc.	1–200	25 min.	28.2	43.4
53,500 spores of blue mold per cc.	1–200	Overnight	29.7	42.1

* All apples given three artificial stem punctures.

The Effect of Humidity of Storage on the Incidence of Rots

The effect of humidity of storage on the incidence of rots was tested for three varieties, Jonathan, Romes and Winesaps. Three different degrees of humidity were provided in cold storage: normal cold storage with an average humidity of 88.2 per cent (81-90); more humid cold storage with an average humidity of 93 per cent (81-100); and low humidity with an average of 81.7 per cent (68-87).

For Jonathans, six boxes from each wet-process machine were packed, three following the drying method adopted for the machine and three immediately after treating and without any drying, thus

giving a dry and wet pack for each of the three degrees of storage humidity. The results as presented in Table 45 show that there was over double the decay in the humid storage that developed in either the normal or the dry storage. There was no appreciable difference in the amount of decay in normal and dry storage. These results also confirm the conclusion already cited that there is but little difference in the percentage of decay in stock that is packed wet or that from which the excess moisture is removed by the machine dryers.

Table 45. Relation of Wet and Dry Packing and Humidity of Storage to Incidence of Decay in Jonathan Apples

Packed, Sept. 23, 1927—Examined, Jan. 7-30, 1928

Storage and type of packing	No. of boxes	No. of apples	No. showing decay	Per cent of decay	Average per cent of decay
Regular cold storage					1.38
Packed dry	10	1428	21	1.47	
Packed wet	7	1064	14	1.31	
Humid or wet cold storage					3.83
Packed dry	11	1655	63	3.81	
Packed wet	7	969	37	3.84	
Dry cold storge					1.37
Packed dry	11	1628	29	1.84	
Packed wet	7	902	8	0.89	

Data based on apples treated over various machines

In the tests with Romes and Winesaps, three boxes from each wet process machine were packed, thus giving one box from each machine for each of the three degrees of storage humidity. The results as presented in Table 46 show no pronounced difference in the amount of decay in the Romes in the three different degrees of humidity, altho there was slightly less rot in the lots stored in the high humidity as compared with the lots in regular and dry cold storage. The results with Winesaps with the least rot under regular cold storage and the most under dry cold storage, throw some doubt on the part which humidity of storage plays in the development of rot. In view of the fact that rot-producing fungi have been observed to make a rather conspicious vegetative growth in the calyx cavity and in the

basin—on and around the stem,—under conditions of humid storage, it would seem logical to expect an increased amount of rot as shown for the Jonathans. It is possible, however, that other varieties may not behave in the same way as the Jonathan. The results with the Romes and Winesaps may possibly be explained by the fact that different degrees of humidity were maintained for only about one-half the storage period of these varieties.

Table 46. Relation of Humidity of Storage to Incidence of Decay in Rome and Winesap Apples

Packed, Nov. 5, 1927—Examinations: Regular cold, Mar. 8-9; Humid cold, Mar. 26; Dry cold April 2, 1928

Storage and variety	No. of boxes	No. of apples	No. showing decay	Per cent of decay
Regular cold storage				
Rome	8	860	11	1.28
Winesap	8	930	2	0.22
Humid cold storage				
Rome	8	881	10	1.13
Winesap	8	963	9	.93
Dry cold storage				
Rome	8	924	13	1.41
Winesap	8	903	11	1.22

Data based on check and seven different wet process machines

The Relation of Calyx Burn to the Incidence of Rots

Arsenical calyx burning of the apples is of importance from two points of view: first, as a blemish or defect that in itself will affect the grade of the fruit; second, as an avenue of entrance for rot-producing fungi, especially blue molds. In the tabulations showing the number of calyx burns for the different varieties and the various machine treatments, those indicated as "slight" would be ignored in inspection and only those classed as "pronounced" taken into consideration (Table 25). If all calyx burns became infected with blue mold or other decays, the cleaning of apples would be very much more of a problem. The actual percentage of calyx burns that developed rots in the four varieties, Jonathan, Delicious, Rome and Winesap, varied from none in the Delicious to 2.21 per cent in the

Jonathans (Table 47). The importance of other avenues of entrance for rot-producing fungi as contrasted with calyx burns, is shown in Table 48. It may be noted that in these tests a very high percentage of the rots or 88.24 to 100 per cent originated from injuries other than calyx burns. From this it would seem that the importance of the calyx burns has been over-emphasized, and that increased attention should be given to reducing mechanical injuries of various types, in other words greater care in the entire handling operations from picking until the apples are finally packed and stored in the warehouse.

Table 47. Showing the Percentage of Calyx Burns Which Led to Decay in Four Varieties over All Machines

Variety	No. of apples	Total no. calyx burns	No. of rots from calyx burns	Percentage of calyx burns developing rots
Jonathan	7733	723	16	2.21
Delicious	2696	37	0	0.
Rome	6152	136	3	2.20
Winesap	6431	154	3	1.94

Table 48. Showing Percentage of Rots from Calyx Burns and from Other Causes of Four Varieties over All Machines

Variety	No. of apples	Total no. of rots	No. of rots from calyx burns	% rots from calyx burns	No. of rots from other injuries	% rots from other injuries
Jonathan	7733	136	16	11.76	120	88.24
Delicious	2696	26	0	0	26	100.
Rome	6152	63	3	4.76	60	95.24
Winesap	6431	46	3	6.52	43	93.48

The results here cited are based on the treatments of four varieties with the seven different wet process machines and five dry wipers. It should not however be inferred that calyx injury is not an element of danger. In all of our experimental tests the customary

precautions to minimize infections were observed, but in some commercial packing operations that have come to our attention, in which cleaning vats and rinse bath were allowed to become heavily contaminated with blue mold, a very much higher percentage of rots could be traced to calyx injury.

The Relation of Open Calyx Canals and Core Injury to Moldy Core and Core Rot.

The occurrence of moldy core and core rot of apples is not peculiar to fruit treated by wet processes for the removal of spray residue, but had been noted previous to the adoption of any cleaning methods, either dry or wet. The open calyx canal offers an opportunity for the penetration of molds and rot-producing fungi into the core cavity. Many apples with an open calyx canal will show fungous filaments in the core cells or growing over the seeds, but only under conditions of abundant moisture do these develop sufficiently to make a conspicious moldy core. The growth of these fungi may be confined entirely to the core cavity or if they happen to be species capable of growing in apple tissue they may invade the pulp of the apple and lead to a core rot or decay advancing from the core outwards. If the core wall is normally sound, moldy core will not lead to core rot. There seems to be two important ways by which a fungous rot is started from the core cavity: first, through growth cracks; and second, through lesions due either to arsenical or acid burning. The two fungi most frequently reported in connection with the core rots are blue mold **(Penicillium spp.)** and black mold **(Alternaria spp).**

Jonathan apples treated by the various wet processes were examined for the occurence of moldy core and core rot with the results shown in Table 49. Some moldy core is shown in apples with open canals in all of the treatments, and seems to have been slightly increased by the wet processes. The significant fact, however, is the occurrence of core rot in the lots treated by the submersion processes, and its absence in the other lots. This is in agreement with the increased core burning shown by the same processes.

The amount of core rot shown by the flotation dip and the box dip was not so great considering the lateness of the storage period when the examinations were completed (Feb. 9-24). The moldy core is of commercial importance in the main from its possible initiation of core rot. On the basis of these records it still would not remove the two processes from having a commercial application. It is unfortunate that we have no definite experimental records of the effect of submerging apples for different lengths of time at various depths. In ranch box washing it has been the practice to submerge the boxes for a greater length of time than was true with the box dips used in our experiments. On the basis of our tests and the disastrous experiences with the Cutler submerger at a number of packing plants, it would seem likely that box dipping carries an element of danger from the liability to induce core rot in any varieties with open calyx canals .

Table 49. Relation of Open Calyx Canals to Moldy Core and Core Rot in Jonathans

Treated Sept. 28—Examined Feb. 9-24.

Type of treatment	Total No. of apples	Total open calyx canals	No. with moldy core	No. with core rot
Check, no treatment	288	56	1	0
Jet spray	278	66	12	0
Fan spray	275	48	9	0
Flotation & spray	251	56	3	0
Flood wash	275	58	8	0
Flotation & dip	275	65	23	4
Box dip	326	49	4	9
Flotation & spray (alkali)	301	56	6	0
Vibrating brush	301	59	4	0

The Effect of the Brogdite-Brogdex Process on the Incidence of Decay

In addition to the lots of Jonathans, Delicious, Romes, and Winesaps used in the entire series of wet-cleaning tests carried out at Wenatchee (Table 25) an opportunity was afforded by the courtesy of the Northwest Brogdex Co., Yakima, to examine certain other untreated and Brogdexed lots of fruit from Underwood, Kennewick, Yakima and Zillah. The lots from Uuderwood were selected because of the known occurrence of perennial canker or bull's-eye rot in

that region in severe form. In all the other sections the principal decay was due to blue molds. Because of the varying conditions to be met the results from the two regions are presented in separate tabulations.

The lots from Underwood were shipped direct from cold storage to Pullman and a portion examined at once (Table 50). The balance of the boxes were held in common storage for two months longer and examined especially for the amount of perennial canker rots and blue mold and other rots. Yellow Newtown and Spitzenberg showed more decay of all kinds in the Brogdexed fruit than in the untreated, but in Jonathan the balance was in favor of the Brogdexed fruit. In all three varieties the perennial canker rot was higher in the Brogdexed boxes than in the untreated. A striking feature of this series was the increase in the perennial canker rot after the fruit had been held for two months longer in common storage. There seemed, however, to be little if any increase in blue mold decay, only one variety, the Spitzenberg showing a marked difference.

The lots of apples from Yakima and Zillah were examined at those places, those from Kennewick were shipped from cold storage to Pullman and part of the boxes examined at once and the others held later as recorded, while the Wenatchee record is based partly on stock held at Wenatchee and on a part shipped to cold storage in Pullman (Table 51). In these lots in which blue mold was the predominating decay there were no striking differences in the amount in Brogdexed and untreated fruit; less rot in the Brogdexed apples in one case and more in another, but showing nearly equal for the average of all Brogdexed and untreated lots (Table 52). The general conclusion from these various tests is that Brogdexing has no marked effect in either increasing or decreasing decay, except in the case of perennial canker, which appears to be increased by the process. It may be noted that the amount of decay in the Brogdexed fruit at Wenatchee is about comparable to that of dry-wiped fruits or of the untreated lots (Table 25). It should be pointed out that the Brogdex process reported to give better protection than drywiping in our work of last season (12) was not the same as the Brogdite-Brogdex process of the past season.

It is also shown by the results reported in Table 53 that fruit packed direct from the alkali cleaner (Brogdite) without the application of the protective coating of oil and paraffin (Brogdex), may show a higher percentage of decay than fruit treated by the complete process.

Tabe 50. Comparison of Untreated and Brogdexed Apples from Underwood, Washington, Showing Percentage and Kinds of Decay

Examined Jan. 12, 1928

Variety and treatment	No. of apples	No. showing decay		% Perennial canker	% Blue mold and other rots	Total % decay
		Perennial canker	Blue mold and other rots			
Yellow Newtown						
Untreated	372	8	0	2.15	0.	2.15
Brogdexed	276	22	1	5.85	.27	6.12
Spitzenberg						
Untreated	263	12	2	4.56	.76	5.32
Brogdexed	263	35	3	13.30	1.14	14.44
Jonathan						
Unreated	251	1	4	.39	1.55	1.94
Brogdexed	276	2	2	.72	.72	1.44

Examined March 21, 1928

Yellow Newtown						
Untreated	391	61	0	15.6	0.	15.6
Brogdexed	263	75	0	28.51	0.	28.51
Spitzenberg						
Untreated	451	190	36	42.12	7.98	50.10
Brogdexed	413	202	45	48.91	10.89	59.80
Jonathan						
Untreated	425	47	11	11.05	2.58	13.63
Brogdexed	451	55	0	12.19	1.99	14.18

Other Effects of the Cleaning and Packing Methods.

Aside from arsenical injury to calyx and core and the decay from rot-producing fungi, several other effects of the cleaning processes may be briefly considered. The possibility of loss of weight due to the effect of dry wiping or the action of the chemical solvents

Table 51. Comparison of Untreated & Brogdexed Apples Showing Amount of Injury and Decay

Variety and treatment	No. of apples	Calyx burn	Scald	Decay (Mostly blue mold)		Total % decay
				Calyx	Side	
Yakima, Wn, Examined Jan. 17, 1928						
Jonathan						
Untreated	200	0	45	0	2	1.0
Brogdexed	188	4	0	0	7	3.72
Delicious						
Untreated	188	0	0	1	0	0.53
Brogdexed	188	3	1	0	0	0.53
Rome						
Untreated	213	0	14	0	6	2.81
Brogdexed	205	0	0	0	2	0.97
Zillah, Wn., Examined Jan. 18, 1928						
Jonathan						
Untreated	288	0	128	0	6	2.08
Brogdexed	313	3	3	2	2	0.64
Rome						
Untreated	164	0	0	0	4	2.43
Brogdexed	226	0	0	0	8	3.54
Kennewick, Wn. Examined 1-12, 1928 (Direct from cold storage)						
Rome						
Untreated	486	0	0	0	15	3.08
Brogdexed	602	2	0	0	8	1.32
Winesap						
Untreated	263	0	0	0	1	0.38
Brogdexed	263	8	0	0	5	1.90
Kennewick, Wn. Examined 3-21, 1928 (After being held in common storage from above date)						
Winesap						
Untreated	376	0	23	3	15	4.78
Brogdexed	388	5	18	2	22	5.66
Wenatchee, Wn. Examined Jan. & Feb., 1928						
Jonathan						
Untreated	764	8		1	1	0.26
Brogdexed	690	178		0	3	0.43
Delicious						
Untreated	281	1		0	3	1.06
Brogdexed	280	23		0	4	1.42
Rome						
Untreated	673	0		1	6	1.04
Brogdexed	614	82		0	6	0.97
Winesap						
Untreated	660	0		0	0	0.0
Brogdexed	632	134		0	2	0.31

Table 52. The Average Percentage of Decay in Untreated and Brogdexed Apples From Various Sources

Variety	Source	Percentage of decay	
		Untreated	Brogdexed
Jonathan	Yakima	1.00	3.72
Jonathan	Zillah	2.08	0.64
Jonathan	Wenatchee	.26	0.43
Delicious	Yakima	.53	0.53
Delicious	Wenatchee	1.06	1.42
Rome	Yakima	2.81	0.97
Rome	Zillah	2.43	2.54
Rome	Kennewick	3.08	1.32
Rome	Wenatchee	1.04	0.97
Winesap	Kennewick	0.38	1.90
Winesap	Wenatchee	0.00	.31
Average		1.33	1.34

on the protecting wax of the apple has been suggested, and some data reported (12). In order to determine if any appreciable loss of weight occurred during storage a total of 155 boxes of packed apples were weighed before placing in storage and the weight again taken after remaining in storage for periods of 130-160 days. (Table 54). On the basis of these tests which included Jonathans, Delicious, Romes and Winesaps in cold and common storage, it may be noted:

Table 53. The Percentage of Rots in Several Varieties Following Brogdite-Brogdex Process and Brogdite Alone

Variety	Brogdite-Brogdex		Brogdite only	
	No. of apples	No. of rots	No. of apples	No. of rots
Jonathan	138	1	138	1
Jonathan	138	0	138	0
Jonathan	125	0	113	2
Delicious	100	0	100	0
Rome	100	1	100	2
Rome	104	0	125	3
Winesap	125	0	113	0
Winesap	100	1	100	1
Total	930	3	927	9
Average % rot		0.32		0.97

(1) that there was but a slight difference in the loss of weight of unwiped, dry-wiped and acid-cleaned fruit, when packed either wet or dry; (2) that the protecting coating of Brogdex appeared to slightly reduce the loss in weight; (3) that the loss of weight following cleaning by Brogdite was comparable to the loss of weight in the checks and in lots cleaned by other processes; (4) that the difference in loss of weight in normal cold storage as compared with high humidity and low humidity cold was variable and without sufficient magnitude to be of much consequence; and (5) that the loss of weight was greater in common storage than in cold storage. The greater loss of weight in one of the two common storage series may be explained in part by the difference in the humidity of the storage, since the Romes were held in a room provided with forced ventilation the floors of which were wet down at intervals with a hose.

Table 54. The Percentage of Weight Lost by Box Lots of Packed Apples Treated by Different Processes

Variety and treatment	Checks		Dry wiped	Washed (HCl)		Washed (alkali)	
	Packed dry	Packed wet		Packed day	Packed wet	Packed after Brogdex ing	Packed after Brogdite
Jonathan							
Normal cold storage	1.8	1.8	1.5	2.5	2.8	0.6	2.3
High humidity cold storage	0.0	2.4	0.8	1.4	1.5	0.6	0.8
Low humidity cold storage	1.8	1.9	2.6	1.8	2.7	0.8	1.9
Delicious							
Normal cold storage	—	0.0	1.4	1.7	1.4	1.6	2.6
Rome							
Normal cold storage	1.1	1.1	1.3	1.1	1.5	1.1	0.6
Common storage	2.2	1.1	2.3	2.1	3.1	1.1	2.3
Winesap							
Normal cold storage	0.6	0.2	1.7	2.7	1.4	1.1	1.7
Common storage	4.8	3.8	4.2	4.5	2.8	4.1	4.4
Average	1.75	1.53	1.97	2.22	2.15	1.37	2.04

Data based on single box lots for checks and Brogdex and Brogdite series, 3-5 box lots for dry wiped fruit and 5-7 box lots for acid washed series. Storage periods: Jonathan, 130 days; Delicious and Romes, 155 days; and Winesaps, 160 days.

No appreciable effects of the dry-wiping or acid-cleaning processes on the incidence of scalds or internal breakdown were noted in any of the storage series which included Jonathans, Delicious, Romes and Winesaps. Since oil wraps were used for these lots no differences were expected. In this connection attention may be directed to the results with Brogdexed and untreated Jonathans at Yakima and Zillah, the untreated stock of which showed a high percentage of scald, mostly soft scald, while the Brogdexed stock showed no scald in the Yakima lot and but a very slight amount in the lot at Zillah (Table 51). It should be noted that in these lots plain wraps were used.

SUMMARY

Investigations were conducted with the 1927 crop for the purpose of testing the efficiency of the processes used to remove spray residues from apples and pears and to afford data for the improvement of the methods of handling.

These experiments dealt with the cleaning efficiency of the processes and with the effect of cleaning upon the storage life of the fruit. They were a continuation and elaboration of the spray residue experiments of the season of 1926. Illustrations and descriptive material are given to show the operating principles of nine wet and five dry-process machines.

At the time of harvest, fruits of uniform average size of practically all of the commercially grown varieties were obtained direct from the orchards. These were subjected to the various commercially operating cleaning processes and were placed at once in a cold storage warehouse. Portions of these samples were used for the determination of arsenical residue which is reported herein as grains of As_2O_3 per pound of fruit.

1. For the 1927 harvest, fruit that required not more than two cover sprays was sufficiently cleaned by dry wiping or brushing. Since most of the irrigated orchards of Washington are in the low-

er parts of the valleys where four to six cover sprays are necessary to combat the codling moth, dry-process cleaning is for the most part unsatisfactory. This was also the finding for the 1926 season.

2. The experiments included a study of the effect of variation in sprays upon the efficiency of the cleaning processes. Averaging the results obtained with seven wet or chemical cleaning processes it was found that when an average or standard spray was used (1 calyx and 4 to 6 covers of lead arsenate at two pounds per 100 gallons) 42 per cent of 89 lots of 10 varieties of apples were cleaned to or below the world tolerance of .01 grains of As_2O_3 per pound of fruit. When special sprays were used (lead arsenate at double strength or with spreaders and oils) the cleaning efficiency of the processes was on the average considerably reduced.

3. On the basis of a decreasing difficulty of cleaning to the world tolerance 48.3 per cent of the Spitzenberg, Yellow Newtown, Jonathan, Winesap, Rome and Arkansas Black varieties were cleaned to or below the world tolerance of .01 and 90.3 to or below the 1927 domestic tolerance of .025 grains per pound of fruit.

4. Averaging the results obtained with Jonathan apples, seven wet and three dry-cleaned processes had the following order of decreasing effectiveness; jet spray, fan spray, flotation and spray, flood wash, flotation and dip, box dip, flotation spray (akali), vibrating bristle brushes, rotating bristle brushes and rotating hemp brushes. These findings are based upon averages obtained from six lots of Jonathan apples for each of the cleaning processes, there having been a different type of spray for each lot.

5. The arsenical loads on uncleaned lots of 11 varieties varied from .015 to .075 with an average of .032 grains of As_2O_3 per pound of fruit. The amount remaining after wet cleaning ranged from .0079 to .015 with an average of .011 and after dry cleaning from .021 to .027 with an average of .024 grains of As_2O_3 per pound.

6. Using the machine that utilized the principle of a fan-like spray of dilute hydrochloric acid directed upon the non-rotating fruit various experiments were made to test the effect of variations in (a) acid strength, (b) number of spray pipes, (c) time of treat-

ment and (d) temperature of cleaning solution upon the cleaning of arsenical residue from Winesap and Arkansas Black apples that had become waxy in cold storage:

(a) At either low, normal or higher temperatures (48° to 98° F.) there was but little betterment of cleaning when the acid strength of the solution was increased by over three times, starting at 0.3 per cent hydrochloric acid by weight.

(b) Doubling the number of spray pipes, wthout altering the pumping system, was without effect irrespective of variations in acid strength, time of treatment, or temperature of solution.

(c) At low to medium treatment temperatures increasing the time of treatment by as much as four times, starting at 32 seconds resulted in but slightly better cleaning of this waxy fruit.

(d) When the cleaning solution was heated to a temperature of 95° to 98° F. a significant increase in cleaning efficiency was obtained as compared to treatments at 48° to 70° F. Increasing the acid strength beyond about 0.3 per cent by weight, added but little to the increased cleaning efficiency obtained in a heated solution.

7. For the efficient cleaning of waxy varieties of apples such as the Winesap and Arkansas Black, discussed above, it is apparent that the temperature of the cleaning solution should be close to 100°F. When the fruit is cool or cold, considerable heating is necessary to maintain the proper temperature of the cleaning liquid. There is also considerable heat loss by evaporation and radiation, especially in a spray-process machine. Proper construction of the machine will reduce these heat losses and thus lessen the cost of cleaning.

8. In a jet-spray process machine a considerable reduction in cleaning efficiency resulted from directing the spray up against the cover of the machine instead of directly against the fruit. An explanation for these results is given.

9. On the average, fruit held in cold storage for four months before cleaning was not cleaned so well as portions of the same lots cleaned in the same way at harvest time.

10. Smaller apples carried larger loads of arsenical residue per pound of fruit than larger apples. This was true after cleaning as well as before. Thus, apples that pack 200 to the box may be expected to have considerably higher arsenical residues than some of the same lot large enough to require only 100 per box.

11. The use of special "apple soap" spray, applied six days before harvest did not remove any of the arsenical residue nor make it any easier to be removed by either dry or wet cleaning.

12. Soluble arsenic accumulated to the extent of .294 grains of As_2O_3 per pound of cleaning solution in a fan-spray machine that had cleaned 900 boxes of apples. The commercial hydrochloric acids used in the 1927 season carried an average of .0016 grains of As_2O_3 per pound of cleaning solution containing 0.3 per cent acid. These findings point out the importance of changing the acid bath once a day to avoid the possibility of arsenical burning of the fruit.

13. Normal and burned calyx ends of apples carried practically the same amounts of total arsenate. No reliable method was available by which the soluble arsenic in the burned calyx could be determined, because of the dissolving action of the malic acid of the juice of the apple upon the lead arsenate spray.

14. All of the wet process machines adapted and used for pears, the pressure jet, fan spray, flotation and spray, and box dip types, cleaned the fruit to or below the world tolerance. The dry-process machines cleaned the Winter Nellis variety sufficiently but failed to remove enough of the residue from the Bartlett and D'Anjou varieties. The dry brush machines, especially the one using vibrating bristle brushes, scratched the surface of the fruit to an objectionable degree.

15. Calyx injury or arsenical burning around the calyx is a type of injury connected with cleaning by wet processes, altho the same type of injury may be found in unwiped apples or in dry-cleaned stock. The following special features have been demonstrated: (a) the Jonathan is very sensitive to arsenical calyx burn; (b) the acid process machcines with a driving or jet spray caused the most calyx

burn, but burning was greatly reduced by turning the jets up against the cover; (c) the submerging processes were also an element of danger; (d) the alkali process (Brogdite-Brogdex) caused as much calyx burning as the most injurious acid process; (e) calyx burning may be very slight or so severe as to send the fruit into the culls; (f) calyx burns may serve as infection courts for the entrance of rot-producing fungi; (g) the ordinary commercial pack (moisture removed by some type of a dryer) shows more burn in common than in cold storage; (h) excessive humidity of cold storage appears to increase burning; (i) dry packing of insufficiently rinsed fruit is more likely to cause burning than wet packing.

16. Arsenical and acid burning of the walls of the core cells may occur in fruits in which there is an open calyx canal. This type of injury is slight with most cleaning processes, but is increased by processes involving submersion of the fruit.

17. The storage rots of the apples in the Pacific Northwest may be placed in the four following groups: (a) blue molds or Penicillium species; (b) the gray molds: (c) the black rots and (d) the anthracnoses. The blue molds are the most important as the cause of decay in storage, no regions being exempt. The perennial canker fungus of the anthracnose group causes heavy losses in a few localities only.

18. Blue mold decay is not a new problem brought into prominence by the new methods of handling apples, but was taking its regular toll before the advent of dry-cleaning methods. Inspection records of car lots of apples at eastern terminals have shown very little difference in the amount of blue mold as a result of dry wiping in 1926 over that in unwiped stock for 1925, while the 1927 crop has shown no marked change, altho there are evidences that there will be an improvement when wet-cleaning methods have finally been standardized.

19. Normal sound apples are carrying a large number of fungous spores on their surfaces, some of which are harmless, while others are rot-producing species. Dry wiping does not remove these spores to any great extent as many are rubbed into the wax the same as spray residue.

20. There is an accumulation of fungous spores in the cleaning and rinsing baths during commercial operations, with little or no killing effect by the solvents used for the removal of the spray residue. These spores originate from the surface of normal apples, from an occasional decayed apple that passes into the machine and from the dust of the air. At the end of the day's run the cleaning bath may contain as high as 12,000 spores of blue mold per cubic centimeter.

21. The importance of keeping down the spore content of the treating and rinse baths is emphasized: (a) by preventing partially decayed apples from going into the machine; (b) by a prewash; (c) by frequent changes of the acid bath; (d) by a continous spray of fresh water as a rinse; (e) by sterilization of the treating bath and rinse over night; and (f) by the use of a fungicide in the regular run.

22. The acid tanks and machines may be sterilized over night by the use of formaldehyde solution, 1 part to 800 of water (for 10-12 hours) being sufficient to completely free the machine of blue mold and other fungi. The use of a 1-400 strength of formaldehyde in the regular run would be equivalent to changing the solutions every five hours.

23. Blue mold will not enter the sound or normal calyx of an apple altho moisture may be present. With present practices there are two main avenues of entrances of blue mold in commercially packed fruit: (a) through mechanical injuries; and (b) through either arsenical or acid burns especially at the calyx end.

24. Packing apples while wet, that is, just as they come from the rinse without any drying treatment, had but little if any effect in increasing the incidence of decay in cold storage stock, while in common storage stock there was a slight increase in decay from wet packing. Wet packing does, however, increase the amount of decay in the case of fruit that shows mechanical injuries.

25. In the case of Jonathans there was nearly three times as much decay in stock held in humid or wet cold storage as in similarly

treated stock held in either regular cold storage or in dry cold storage. Romes under somewhat similar conditions showed no appreciable difference in the three types of storage, while the effect of humidity of storage on the incidence of rots in Winesap apples appears somewhat uncertain.

26. While arsenical calyx burns may serve as infection courts for fungi, especially blue mold, only a very low percentage become infected under well-regulated packing conditions as furnished in our tests (none in Delicious to 2.21 per cent in Jonathans). Mechanical injuries were shown to be much more important as infection courts for rot-producing fungi than calyx burns.

27. The percentage of decay in the wet-process machines for the four varieties and seven machines compared ranged from 0.67 in the flotation and spray (alkali) to a maximum of 3.19 for the jet-spray machine, as compared with .50 for the untreated lot and a range from 0.17 for the bristle brush wiper to a maximum of 0.99 for the rotating horse hair brushes. The decay in all cases was less than shown last year for the same varieties from the Kennewick District.

28. Open calyx canals offer an opportunity for the penetration of molds and rot-producing fungi into the core cavity, with the development of either moldy core or a core rot. Moldy core may lead to core rot in either of two ways: (a) through growth cracks; or (b) through lessions due to acid or arsenical burning. Moldy core was silghtly increased by the wet processes, but core rot was noted only in fruit treated by the submersion processes, which was in agreement with the core burning by the same processes.

29. The effect of the Brogdite-Brogdex process on the incidence of decay was studied on storage lots from five different localities. The following may be noted: (a) Packing wet direct from the Brogdite gave a slight increase in the decay over the similar lots given the protective coating; (b) the average percentage of blue mold decay for five varieties from four localities was practically equal in the untreated and in the Brogdite-Brogdex treatments; (c) Brogdexing did not control perennial canker rot in lots from Underwood, there being an increase over the untreated for the three varieties tested,

when taken direct from cold storage; (d) there was a still further increase in perennial canker rot when the same stock was examined two months later in common storage; (e) the susceptibility of the three varieties tested was in the following order: Spitzenberg, Yellow Newtown, and Jonathan.

30. The various dry-wiping and wet-process treatments of Jonathans, Delicious, Romes and Winesaps held in both common and cold storage showed: (a) Slight if any difference in loss of weight of dry-wiped and acid-cleaned fruit; (b) loss of weight following Brogdite only was comparable to checks and lots cleaned by other processes; (c) Brogdexing reduced the loss of weight slightly; (d) the loss of weight was greater in common storage than in cold storage, but weight loss under different conditions of humidity in cold storage was variable; (e) neither dry wiping nor acid cleaning had any appreciable effect on scald or internal breakdown; (f) soft scald was almost completely prevented in certain lots of Jonathan apples by the Brogdite-Brogdex process.

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